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An Optical Primer

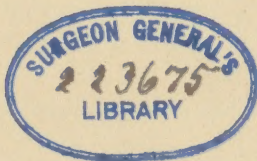
THE MAJORITY OF THE ARTICLES IN THIS BOOK
INCLUDING THE SPECIAL ARTICLE ON
"TRIAL LENSES AND HOW TO USE THEM"

WERE WRITTEN

BY

CHAS. H. PIXLEY

AND THE BALANCE BY EXPERTS IN THE
PARTICULAR FIELD COVERED BY
THE INDIVIDUAL ARTICLE



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TRIAL LENSES AND HOW TO USE THEM.

An actual test with trial lenses always has been, and always must be, the final test for the correction of refractive errors.

The trial case then is the supreme court, or, as it has been aptly termed, "the court of last resort." To this court, then must come for final adjudication the findings of all other tests, whether they be subjective or objective, monocular or binocular, or whether they be made with or without the aid of instruments, or with or without the use of cycloplegics.

The trial case test, then, being the supreme test, either approves of or modifies the results obtained by all other tests.

The trial case test being the supreme and final test, should result in securing for the patient good and comfortable binocular vision. If this desirable end is to be obtained, the operator should thoroughly understand the underlying principles of ocular refraction. He should also understand the action of lenses and just how to manipulate them to the best advantage.

A trial case, then, is absolutely indispensable and becomes the most important part of an oculist's or an optometrist's outfit. Such a case should be well made, quite complete, and absolutely correct as to the numbering, centering and axis marking of its lenses, every one of which should be of the very best quality. A lens that is defective in any sense, or one that is second quality, should have no place in a trial case.

Contents of a Trial Case.

The contents of a trial case which may be considered fairly complete, or complete enough for practical purposes, consists of 37 pairs of convex spherical lenses and the same number of concave sphericals, 24 pairs of convex cylindrical lenses and the same number of concave cylinders, 16 prisms, 5 plano smoke, 1 plano red, 1 plano blue, 1 plano green, 1 plano

amber, and 1 plano white lens, 2 crossed cylindrical lenses, 1 red multiple Maddox rod, 1 Maddox double prism, 1 Cone muscle test, 1 chromatic test, 2 pin hole discs, 2 stenopaque discs, 2 cross line discs, 1 ground glass disc, 1 opaque disc, an axinometer and an optician's rule. The case should also contain a three cell adjustable trial frame of the most approved pattern, and a trial frame with two open cells.

The contents of a trial case may exceed the above; in fact some of them contain as high as 48 pairs of convex and concave spherical lenses and 28 pairs each of convex and concave cylinders. There are also trial cases containing fewer lenses and discs; in fact a case containing only a few pair of spherical lenses and a single cheap trial frame may be called a trial case.

Between the ones having the greatest number of lenses, discs, frames, etc., and the ones having the least number, there are numerous styles, some of them being styled "office cases," some "traveling cases," and others "pocket cases," and still others are styled "retinoscopic cases."

There should be a sufficient number of spherical, cylindrical and prismatic lenses in a trial case to enable an operator to make a thorough test without having to double them up too much.

Trial Lens Rims.

All the lenses, discs, rods, etc., should be mounted in metal rims, the diameter of which should be exactly $1\frac{1}{2}$ or $1\frac{1}{4}$ inches. The rims on all minus lenses should be gilded, and those on all others should be nickel plated. It will then be an easy matter to differentiate readily between those having positive and those having negative power. Strong, short handles should be placed on all the rims. The handles should have a flat space close to the rim, large enough to contain the number of the lens, which should be stamped upon both sides of the handle, so that it may read from either side. The figures should be large enough to be seen in a moderately dark room, and close to the rim so that they may be seen when the lens is held by the handle between the thumb and finger.

Arrangement of Lenses.

The arrangement of the lenses in the case should be as shown in Figs. I and II, the $+$ lenses in the end to the right, and the $-$ lenses in the end to the left; the cylinders, prisms, etc., being in the center. Between the rows of lenses, which should be arranged in pairs, there should be a raised strip, upon which should be printed the number of the lenses which occupy cells opposite. The trial frames and rule should occupy a space in the center of the case at the front.

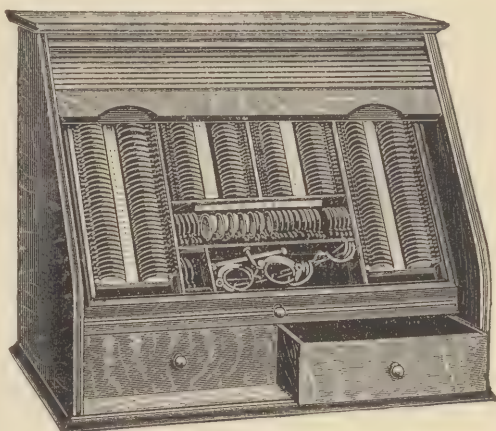


Fig. I.

Lens Tray.

The tray carrying the lenses should be removable from the case, and should be open at the bottom, so that any dirt or dust that may accumulate may drop out of the lens cells when the tray is lifted from its case. The tray of a traveling case should have a sliding bottom that may be removed for the purpose of cleaning. Everything contained in a

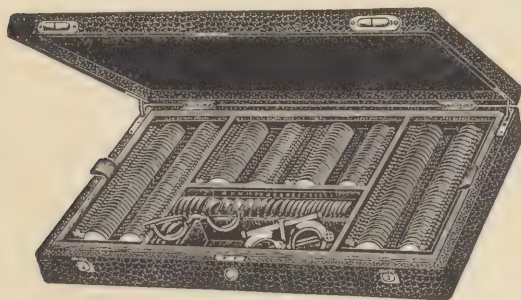


Fig. II.

trial case should be kept scrupulously clean and aseptic. This is especially true of the lenses and the trial frames. Every lens, disc, etc., should have its particular place in the tray and be kept

there so that it may be found at once when wanted. The case may be leather covered with leather partitions between the lenses, or it may be made of wood to match the office furniture.

Numbering Trial Lenses.

It was stated at the beginning of this article that every lens should be numbered correctly. This is true; even the high power lenses should vary but a trifle from being the exact power stamped upon the handle. The powers of those weaker than 10 dipters should be absolutely correct.

Centering Trial Lenses.

The optical centers and the geometrical centers of the spherical lenses should exactly coincide. If trial lenses are not perfectly centered, errors in estimating ocular muscle imbalances are likely to occur. Such lenses also cause confusion and contradictory results when neutralizing prescription lenses in which there is a prismatic element.

Axis Marking.

The axis of the cylindrical lenses should be plainly marked by a scratch at the outer edge of the lenses, or by etching, as shown in Fig. III, and this scratch should indicate the exact axis. The cylinders should also be etched at their sides; the etching being quite narrow and parallel to the axis.

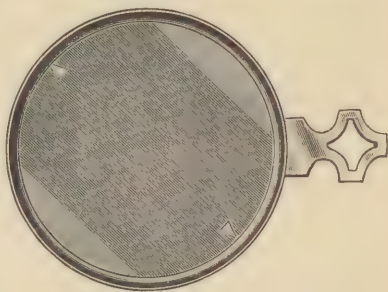


Fig. III.

Base of Prisms.

The base apex line of the prisms should also be marked at both sides, similar to the marking of the axis of the cylinders.

Handles.

The handles on the cylindrical and prismatic lenses should occupy a position of 45 degrees from the axes of the cylinders and base apex line of the prisms.

Colored Lenses.

The five plano smoke lenses should be of assorted shades; they should have the number of the shade stamped upon the handles, similar to the numbering of the lenses. The standard shades are numbered from "0," which is very light, to "7," which is very dark. The red, blue, amber and green lenses should be of medium shades. The different shades of these lenses are numbered practically the same as are the smoke.

Crossed Cylinders.

A cross cylinder lens has plus powers in one meridian and minus power in the other. One of these lenses should have a total cylindrical power of 0.50-D, and the other a power of 1.00-D.

Pin Hole Discs.

The pin hole discs are plain rubber discs with small perforations at the center. The hole in one should have a diameter of about 1 mm. and the other a diameter of 4 mm.

Cross Line Discs.

The cross line discs should be plano white lenses, having lines scratched at right angles to each other through their centers.

Solid Rubber Disc.

The solid rubber disc should have a gilded rim to distinguish it from the other discs.

Stenopaic Discs.

The stenopaic discs consist of hard rubber discs, slotted through their centers; the slots in each varying in width.

Chromatic Disc.

The chromatic disc consists of a shade of Cobalt blue glass of the correct density to exclude all but blue and red rays of light. The blue rays being more refrangible than the red are brought to a focus at one point while the red or least refrangible rays are focused at another point.

Ground Glass Disc.

The ground glass disc is a plano white lens frosted. It admits light to the eye, but prevents its seeing.

Plano White Lens.

The plano white lens is for use when one eye is normal.

Maddox Multiple Rod.

The Maddox multiple rod consists of a series of small white or red glass rods or cylinders mounted in the center of a black rubber disc. If these rods are made from fluted glass the glass must be of the same thickness throughout or the rod itself will be prismatic and therefore worse than worthless.

Maddox Double Prism.

The Maddox double prism consists of two small prisms of about four degrees each, mounted in the center of a rubber disc; their bases being together the diameter of the two should not exceed 7 mm.

Cone Prism.

The cone prism consists of a cone prism cemented to a ground glass disc. Such a prism produces a circle of light.

Axonometer.

The Axonometer consists of a black disc with a 5 mm. opening in its center. It has a broad white line drawn across it from side to side. The line, as the name of the instrument implies, indicates an axis.

Rule.

The optician's rule should be 15 cm. long. It should be graduated in centimeters and millimeters on one side, and in inches and 16ths of an inch on the other. Practically all measurements for spectacles or eye glasses should be given in millimeters. When this is done, the measurements are all given in whole numbers, thus eliminating all fractions and reducing the chances of errors in writing or in reading the measurements correctly to the minimum.

The Trial Frame.

In order that the trial lenses may be held correctly in front of the patient's eyes, there must be a series of trial frames of different dimensions or a single one having many adjustments. These adjustments are for pupillary distance for height of bridge, for inclination of bridge, for distance between temples and for length of temple. The bridge should be



Fig. IV.

swiveled so that it will automatically adjust itself to any angle that the patient's nose may have. There should be three lens cells for each eye; two that may be used for spherical and one for cylindrical lenses; the latter cells being rotatable. The cells should be made to hold a lens the diameter of which is exactly $1\frac{1}{2}$ or $1\frac{1}{4}$ inches. There should be suitable springs for holding the lenses in the cells and scales showing the different adjustments and the axis of cylinders. The latter scales should be numbered in degrees of half a circle from "0," the starting point on the left of the horizontal line, to 180 on the right of the horizontal line; thus covering one-half of a

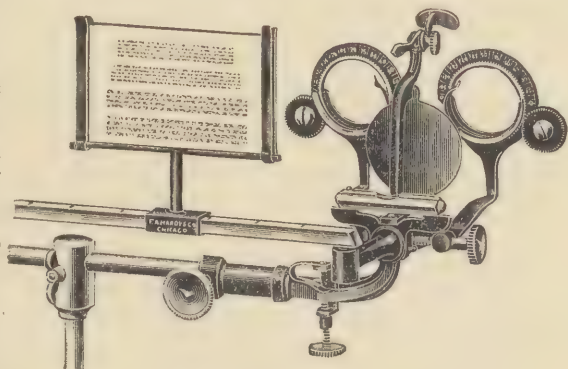


Fig. V.

circle; the horizontal being "0" or "180" and the vertical "90." These scales should be mounted on the frame, so that a vertical line drawn through "90" and a horizontal line drawn through

"0" and "180" will cross exactly in the center of the cells. If such lines do not cross in the center of the cells or of the lenses, when they are in the cells, the axis of the cylinder would not be correctly indicated. For this reason the cells and the lens rims must be exactly the same size. The meridian scales should be numbered at 5° intervals with marks showing $2\frac{1}{2}^\circ$. A trial frame, such as described above, is necessarily heavy and therefore a tortuous instrument. One practically the same, but mounted on an adjustable stand or bracket, and having a spirit level attached, relieves both operator and patient of much annoyance and discomfort. See Fig. V.

Open Cell Frame.

The frame with open cells, being much lighter, is for use when it is desirable to have the patient wear a correction for a short time while in the office. These frames, like the others, should have meridian scales so that the axes of cylindrical lenses may be properly placed.

Letters for Testing Distant Vision.

The lowest angle under which two points may be distinguished from each other has been taken as a unit of measurement for visual acuity. Hooke found that this angle corresponds to one minute, and Helmholtz later found practically the same angle. For instance, they found that a double star in order to be recognized as such by the eye, must have a separation equal to one minute. Ophthalmologists, therefore, adopted this angle as a unit of measurement for visual acuity. An eye that can discern an object under the above angle is said to have normal acuity.

Standard letters, known as Snellen's, are based upon this angle. The three limbs of these letters and the two spaces between the limbs each subtend an angle of exactly one minute, the whole letter subtending an angle of five minutes when viewed from the distance named above the letters. Rays of light from an illumined object that have traveled six meters or more before they enter the eye are practically parallel. Therefore the above distance (six meters) is generally used when making a test for visual acuity or for an error

of refraction. The size of a one minute angle when the radius is six meters is obtained in the following manner:

The diameter of a circle, the radius of which is six meters, is twelve meters, or 12,000 millimeters. The circumference of this circle in mm.'s would be 12,000 multiplied by 3.1416, or 37,699.2000 mm.'s. To get the number of mm.'s in one degree, the above is divided by 360. We therefore have 104.72 mm. in one degree. One sixtieth of this sum, or 1.74 mm., is, therefore, one minute, and this multiplied by five gives us 8.70 mm. as the size of our standard 6 m. letter.

The acuity of many eyes, especially those of children, exceeds the standard. There are, also, many eyes the acuity of which falls far below the standard. Therefore several different sizes of letters are necessary for testing purposes. See Fig. VI.

An eye possessing only $1/10$ of normal acuity would not be able to name a letter that subtended an angle of less than 50 minutes at 6 meters. On the other hand, an eye possessing normal acuity plus $5/10$ would be able to name one subtending an angle of only $3 \frac{1}{3}$ minutes at the above distance.

In order that the visual acuity may be measured accurately and named or recorded comprehensively the interval between the different sizes of letters should always be the same. For in-

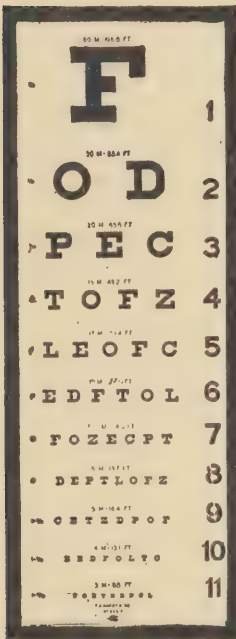


Fig. VI.

stance, each interval should correspond to one or more tenths of the standard.

A letter that subtends an angle of fifty minutes at six meters represents exactly $1/10$ of normal acuity; one that subtends an angle of twenty-five minutes, $2/10$; one that subtends an angle of ten minutes, $5/10$, etc.

To obtain the size of a letter representing $1/10$ of normal acuity, multiply the size of the standard six meter letter by ten.

We, therefore, have 87.00 mm. as the standard for $1/10$ of normal. Such a letter subtends an angle of fifty minutes at six meters and an angle of five minutes at 60 meters. It is known as a 60 m. letter.

The size of a letter representing $2/10$ of normal is obtained by dividing 87.00 by 2. If we divide by 3 we obtain the size of one representing $3/10$ of normal; if by 4, $4/10$; if by 8, $8/10$, etc. If we divide by 12 we obtain a letter representing normal acuity $+ 2/10$; if by 15 normal $+ 5/10$, etc.

We may also divide the distance, 60 m., by 2, 3, 4, 5, 6, etc., to obtain the distance at which each of the letters subtend an angle of five minutes. If we divide by 2 we get 30; if by 3, 20; if by 4, 15 meters, etc. We therefore have on our test cards 60- 30- 20- 15- 12- 10 and $7\frac{1}{2}$ meter letters representing respectively 1, 2, 3, 4, 5, 6 and $8/10$ of normal vision.

We also have 6, 5, 4 and 3 meter letters representing respectively normal, normal $+ 2/10$, normal $+ 5/10$ and normal $+ 10/10$.

A card with letters as above will have eleven different sizes of letters. The smallest of these that the patient can name when seated six meters from the card (which should be well illuminated) represents their visual acuity.

Recording the Visual Acuity.

The visual acuity may be named or recorded in tenths of the standard or as $4/10$, $6/10$ normal, or normal $+ 2/10$, etc. A patient may not be able to name letters representing more than 4 or $6/10$ of normal before correction and normal or better after. Such patients may be informed in terms which they will understand exactly how much their vision may be improved with lenses.

The visual acuity may also be recorded in fractions, the numerator of which expresses the distance of the patient from the test letters and the denominator the number of the smallest ones that can be named. For instance, if the patient is seated six meters from the card and the 12 meter letters are the smallest that can be read, the visual acuity could be recorded as $6/12$ (the equivalent of $5/10$). If they are able to

read the four meter letters, the acuity could be recorded as $6/4$ (the equivalent of normal $+ 5/10$), etc.

The former method, however, is far easier to understand, especially by the patient.

Visual acuity may be defined as the amount of vision possessed by an eye after any error of refraction that may exist has been corrected. However, records should show vision with and without corrective lenses. The lithographic process of producing test type is very expensive, yet it has been found by

experience that test letters to be perfect must be produced by the above process. In printing from types printer's ink seems to run a little. This makes the limbs of the letters a little too wide and the spaces between the limbs a little too narrow. This is especially true with the smaller letters, and these are the very ones that should be quite perfect. Several cards of test type with the order of the letters changed should accompany the Trial Case. This is necessary because patients not infrequently commit them to memory.

Aliens' Card.

There should also be a special card for aliens who do not know the English letters. Fig. VII represents such a card. The characters of this card consist of lines shaped like the capital letter "E." They are made to conform to the five

minute angle. These letters are variously placed, and the patient must indicate with his fingers the direction in which the prongs of the letters point, whether to the right or left, up or down.

Children's Card.

There should also be a picture card for testing young children's eyes, or those not able to name the letters. Pictures cannot be drawn to a five minute angle, yet they will enable

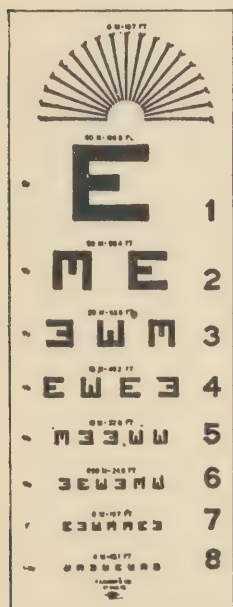


Fig. VII.

are used to locate subjectively the principal meridians of an astigmatic eye. The one most generally used is known as the clock dial chart (see Fig. IX), and ordinarily it will be found to answer the purpose. It consists of a series of three uniform black lines lying parallel to each other, with white spaces between them, which should be of the same width as the lines. Each line and each space will then subtend an angle of one minute at a certain distance, *which should be stated on the Chart*. If the distance is six m., the lines and spaces will be 1.74 millimeters wide, or a total of 8.70 mm. for the three lines and two



Fig. IX.

spaces. Astigmatic Charts which are correct for 6, 7.50, 10, 15 and 20 meters are to be had, but generally speaking these Charts are very imperfect.

If the clock dial test is to be a delicate one, the six meter chart should be used at six meters, or if the so-called fogging method of testing be used, and the vision is fogged to the 15 meter line of type, the 15 meter Astigmatic Chart should be used. The reason for this is apparent when it is known that the letters in the 15 m. line are the smallest that can be named, and if they are named we know that one set of lines on the 15 m. Astigmatic Chart will be seen, and that the others will be more or less blurred, according to the amount of astigmatism present. If the 10 m. letters are the smallest that can be named at 6 m., then a 10 m. Chart should be used. As stated above, the purpose of the Astigmatic Chart is to detect by the patient's answers whether astigmatism is present, and if so, in which meridian.

The Chart should be so placed that the lines numbered 90 (the vertical ones) are perfectly vertical.

The Chart should never be hung at an angle, and must be perfectly flat. It should also be highly illuminated, and on a level with the patient's eyes.

The interval between the lines on the ordinary clock dial charts is 30 degrees. Therefore, only six meridians are indicated, namely, the horizontal or 0, 30, 60, 90, 120 and 150.

The above meridians may be indicated by the patient as follows: 0 or horizontal from 9 to 3 o'clock; 30 from 2 to 8 o'clock; 60 from 1 to 7; 90 from 12 to 6; 120 degrees from 11 to 5; and 150 from 10 to 4 o'clock. A chart with intervals of 15 degrees or one in which the interval is only 10 degrees is often found useful. See Fig. X.

With such a chart one is able to locate the principal meridians with much greater accuracy, especially if the astigmatic error be great. Dr. Parker's Modified Verhoeff Chart or the Thomas Chart with revolving cross lines, which may be placed so that they will lie in the two principal refracting meridians, are very useful. See Fig. XI.

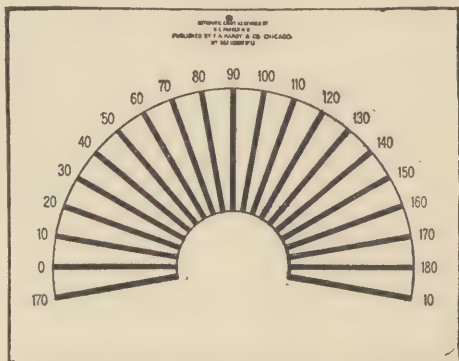


Fig. X.

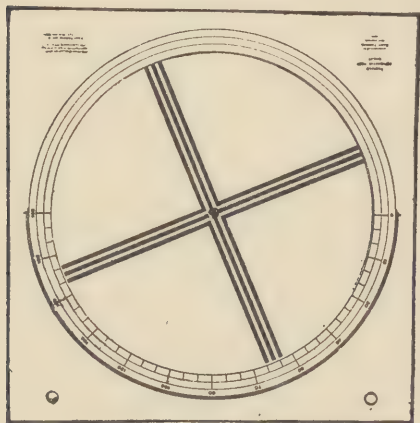


Fig. XI.

The head of the patient being examined must be perfectly vertical, as well as are the 90th meridian lines on the chart. Each eye must be examined separately, one being covered but not closed. If no astigmatism be present all the lines will appear equally black or distinct, but if the patient selects one set of lines as blacker than are the others, then the presence of astigmatism is indicated and the lines noted as the blackest lie in the meridian of astigmatism. If the chart be

of the clock dial order the horizontal lines (those from 9 to 3) may be selected as the blackest. If they are the astigmatism is in the vertical meridian, but if the vertical lines, or those from 12 to 6, are the blackest, then it is the horizontal meridian which is astigmatic.

Axis of Cylinder.

The axis of the correcting cylinder must lie in the meridian at right angles to the lines named as the blackest. For instance, if the horizontal lines are the blackest, the axis of the correcting cylinder should be placed vertical, or if the vertical lines are the blackest the axis should be placed horizontal.

Astigmatism With the Rule.

If the astigmatism be what is known as "with the rule" and *hyperopic*, the patient will select the horizontal lines, or those nearly horizontal, as the blackest ones. In such a case a $+$ cylinder, axis vertical, or at right angles to the lines named as the blackest, will be indicated. If the astigmatism be with the rule and *myopic*, the vertical lines, or those nearly vertical, will be selected as the blackest ones. In such a case a $-$ cylinder, axis horizontal, or at right angles to the lines named as the blackest, will be indicated.

Astigmatism Against the Rule.

Should the astigmatism be what is known as "against the rule," the above order regarding the axis of $+$ and $-$ cylinders would be reversed. In other words, if the astigmatism is *hyperopic* and against the rule, the axis of the cylinders should be placed in the horizontal meridian. If the astigmatism be *myopic* and against the rule, the axis of $-$ cylinders would be placed in the vertical meridian. It should be clearly understood that if the vertical meridian, or the meridian lying nearly vertical, has the greatest refracting power, the astigmatism is with the rule, but should the horizontal meridian, or the meridian lying nearly horizontal, have the greatest power, the astigmatism is against the rule.

It should also be clearly understood that a $+$ cylinder adds power to the meridian at right angles to its axis, and that a $-$ cylinder neutralizes power in the meridian at right angles

to its axis. Therefore, the axis of a $+$ cylinder must be in the meridian of greatest power, and the axis of a $-$ cylinder must lie in the meridian of least power, or least refraction. In these positions the former adds power to the meridian of least, and the latter neutralizes power in the meridian of greatest refraction; thus they equalize the two meridians.

If the meridians of least and greatest power have been obtained by the use of an Ophthalmometer, Punctumeter, Retinoscope, or by other means, the axis of the correcting cylinder may be placed practically correct at once. If the eye is myopic, or has been rendered so by placing $+$ spherical lenses, called "fogging lenses," before it, the lines which appear first as the fog is cleared up with $-$ spherical lenses, represents the meridian of least refraction, and in this case the meridian of least error, and a $-$ cylinder of the correct power with its axis in the meridian at right angles to the lines first appearing, will correct the error.

Symmetrical Astigmatism.

As a rule the meridians of greatest and least power are symmetrical in the two eyes. For instance, if the right eye selects the vertical lines as the blackest, the left eye will select the same, or if the lines from 11 to 5 are selected by the right eye, those from 1 to 7 will be selected by the left, but one eye may select vertical and the other oblique lines. When this is the case the astigmatism is not symmetrical. If the two meridians added together produce 180, the astigmatism is said to be symmetrical. For instance, 90 and 90, or 70 and 110, or 45 and 135 equal 180, but 60 and 90, or 20 and 130 do not. Unsymmetrical astigmatism is more difficult to correct satisfactorily than is symmetrical, especially if the error be slight. If the astigmatic error is of small amount, the patient may not be able to name any lines as being the blackest until after any spherical error that may exist has been corrected.

Illumination of Test Charts.

It was stated above that the test letters should be well illuminated. We will supplement that statement by saying that the letters should not only be well illuminated but the illumination should be even and constant or always the same,

so that a record made today may be repeated tomorrow, or one made on a very bright day may be duplicated on a dark day.

This means that some one of the many schemes for artificially illuminating test charts should be used. There are two distinct methods of illuminating test type, both of which have their advocates. One method is to reflect a flood of light on the test chart, and the other is to illuminate the letters by light passing through some translucent material like opal

glass or unmottled paper. When opal glass is used the printing is done with black enamel, which is finally burnt in making the letters permanent.

Test type lithographed on translucent paper and illuminated from the back has been found very satisfactory. Cabinets containing such type, which may be operated from a distance, are quite popular. (See Fig. XII.)



Fig. XII.

Letters or Type for Testing Near Vision.

To determine the near point of distinct vision, known as the punctum proximum (abbreviated P.p.), test letters or type in the form of words or sentences are employed. These letters, like those employed for testing distant vision, should subtend an angle of five minutes at a given distance, which distance should be noted on the card above the type. For instance, letters suitable for testing at a distance of one meter (40 inches) measure 1.43 millimeters, indicated " $D = 1.00$ ". Those suitable for half a meter measure 0.73 mm., indicated " $D = 0.50$," and those suitable for a distance of one fourth of a meter measure 0.36 mm., indicated " $D = 0.25$."

The letters or cards now obtainable do not as a rule conform to the above dimensions, for the reason that type that measures less than three-fourths of a millimeter (0.75) is not found in a printer's outfit. The smallest letters usually found on near point test cards are about three-fourths millimeters square. This size does well when the near point (P. p.) is one-half meter distant, but when brought closer than the above distance such letters subtend an angle greater than five minutes, and if brought as close as one-fourth of a meter (10") they subtend an angle of ten instead of five minutes. They are therefore entirely too large for that distance. For this reason a patient will be able to read them closer to the eye than his actual near point, or P. p.

The P. p. of a child 10 years of age and possessing a normal eye, is, or ought to be, practically 7 cm., or $2\frac{3}{4}$ inches from the eye. It is practically impossible to produce type small enough to be correct for that distance; in fact for any distance less than $\frac{1}{3}$ of a meter (13 inches). When the P. p. is less than this distance we must resort to some other method of locating it. For practical purposes type suitable for the following distances, viz.: 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 and 2. meters is sufficient, but most cards have type suitable for greater distances, or up to 4. meters (indicated D. = 4. m.).

Locating and Recording the Near Point (P. p.).

When wishing to locate the P. p. the patient is handed a near point test card, which must be held in a good light, and asked to read aloud the smallest type on the card that he can see distinctly. He is then asked to bring the card as close to his eye (one being covered) as possible and still make out the letters. Each eye should be tested separately for there may be a distinct difference between them and the knowledge of this fact is important.

The distance from the eye at which the card is held and the number of the smallest type that can be seen should be recorded. For instance, if 0.50 type is read at 10 cm. and no closer, the record would be near points equals type 0.50 D at 10 cm., or if 1.00 D type is the smallest that can be read,

and this not closer than 30 cm., the record would be near point equals 1.00 D type at 30 cm.

A tape measure or a meter rule graduated in cm. and mm., the latter being preferred, should be placed against the patient's cheek, and the distance that the card is held from the eye carefully noted in cm. and fractions. If the patient is not able to read any of the near point type without the aid of lenses a + sphere of sufficient power to enable him to read some of the small type should be placed before the eye, and this sphere, together with the type read and the distance it is held from the eye, should be recorded. For example, if a + 1.00 sphere is employed and type 0.50 D is read at 20 cm. and no closer, the record would be near point equals type 0.50 D at 20 c.m. with + 1.00 D sphere. Or this may be abbreviated thus: "+ 1.00 S = 0.50 D. at 20 c.m."

Power of Reading Glasses Indicated.

The smallest standard type that a presbyopic patient can read without glasses when holding the card at his natural reading distance and in a good light, indicates approximately the lenses he requires for reading or for close work. For instance, if the 2.00 D type is the smallest that can be read, + 2.00 spheres are indicated; if 4.00 D is the smallest that can be seen, then + 4.00 spheres are indicated.

Powers of Spherical Lenses Indicated.

Under certain conditions the visual acuity is an index to the spherical lens required to produce normal vision or better.

The conditions required are:

First—That the ciliary muscle shall be at rest when the test is made.

Second—That the eye must be capable of obtaining 6/6 vision, or better.

Third—That the test be made at a distance of 6 meters.

Fourth—That any astigmatism that may exist be corrected before the test for acuity is made.

Fifth—That the test type used shall measure the acuity in tenths of the normal.

Under the above conditions the visual acuity is an index

to the spherical lens (+ or —) required to give 6/6 vision, and the same lens which will give a vision of 6/6 will also give a vision of more than 6/6, provided the acuity of the eye, being examined, is greater than the standard for normal.

The reason for the fifth condition is that the interval between the different sizes of letters used to test the acuity must be perfectly uniform. Each line must represent exactly one, or more tenths of normal vision. For instance: A 60-meter letter is ten times the size of a 6-meter letter; it, therefore, represents but one-tenth of normal acuity if viewed from a distance of 6 meters; a 30-meter letter would represent two-tenths; a 20-meter, three-tenths; a 15-meter, four-tenths, and so on.

It has been demonstrated that for each one-tenth of acuity that the eye is shown to be deficient, it requires a one-fourth diopter lens (0.25) to bring the acuity to normal or better.

For instance, an eye that is deficient four-tenths requires four quarters, or one diopter, to bring its acuity to 6/6. If it is deficient seven-tenths, it requires seven-quarters, or 1.75, to bring its acuity to normal. We will suppose that a patient seated 6 meters from the test type can only name the 60-meter letters. We know that these letters are ten times as large as are the 6-meter letters. They, therefore, represent one-tenth of normal acuity. Such a patient is, therefore, deficient nine-tenths, and according to the above rule would require nine quarter diopters or 2.25, to raise their acuity to 6/6. If the above rule is practically or even partially true, the time consumed in making the subjective test may be greatly reduced. Not only this, the fatigue caused the patient by a long and tedious examination will also be materially reduced, and this ought to enhance the value of the results finally obtained. According to the above rule, a patient (with accommodation suspended) that cannot name the 60-meter letters, requires a + or — spherical lens of 2.50, or stronger.

Trial Lenses.

Trial lenses, or those used for testing purposes, have character, form and power. The character of a lens depends upon the curves given its surfaces. If these curves are spherical

the lens is known as a sphere (abbreviated "Sph." or "S."). If the curves are cylindrical the lens is known as a cylinder (abbreviated "Cyl." or "C.").

If the lenses are wedge shape and have flat surfaces, they are known as "Prisms" (designated by the sign " Δ "). If the curves given the surface are convex, the lens is said to be a "positive" one, or to have a "real" focus. Such lenses are commonly called "plus" and are designated by the sign "+." If the curves are concave the lens is a negative one, or one having a virtual focus. Such lenses are commonly called "minus," and are designated by the sign "—." Convex and concave spherical lenses are so called because they are segments of a sphere, the + being segments of a solid sphere while the — are segments of a hollow sphere. Cylindrical lenses are segments of a cylinder, the + being segments of a solid and the — segments of a hollow cylinder.

It will be seen by the above that one meridian of a cylinder is not curved. Such a meridian, therefore, has no power, it is known as the "axis." The meridian at right angles to the axes is curved, and this meridian is the only one that has focusing power. A + cylindrical lens, therefore, focuses only those rays of light which strike it at right angles to its axis; such rays being brought to a focus in a straight line, parallel to the axis rather than to a point, as they would be by a + spherical lens.

The focus of a — cylinder, like the focus of a — sphere, is virtual, and may be found by following the divergent rays of light back to a point or to a line from which they seem to have come.

Prisms are wedge-shaped lenses having flat surfaces. The thick edge of a prism is known as its base, and the thin edge as its apex. Rays of light that pass through a prism are bent or refracted towards its base. This causes the image of an object viewed through it to be displaced towards its apex.

Spherical and cylindrical lenses may be looked upon as made up of an infinite number of prisms which present an infinite number of refracting angles. If the lens be convex spherical (+) the bases of the prisms constituting it are directed towards the thickest part of the lens, known as its optical

center. Just the opposite is true of the prisms constituting a spherical concave (—) lens, for in this lens the apices of the prisms are directed toward its optical center, which is the thinnest part of the lens.

As stated above, light in passing through a prism is bent towards its base; therefore convex lenses converge and concave lenses diverge light rays. For this reason they are often called “converging” and “diverging” lenses. Convex lenses are also known as magnifying lenses, for the reason that they magnify an object viewed through them, provided the object is closer to the lens than its principal (shortest) focus. The same object viewed through a concave lens is diminished in size; therefore they are known as “mimifying” lenses.

As a rule the form of the spherical lenses in a trial case are biconvex and biconcave. They are then known as “double convex” (abbreviated Dcx.) or double concave (abbreviated Dcve.) lenses. The cylindrical lenses are plane on one side and convex or concave on the other.

Plano Spherical Trial Lenses.

It is the opinion of the author that the spherical as well as the cylindrical lenses in a trial case should be plano convex and plano concave. For the reason that trial lenses must be used for neutralizing purposes and the plano spherical form is by far the best form for that purpose. They are also superior to the bi-spherical form for testing purposes, because of the possibility of their being built up in the periscopic form.

A Trial Case worthy of the name will have a fair assortment of both + and — spherical lenses and + and — cylindrical lenses and prisms, either of which may be used separately or in combination with one or both of the others.

Numeration of Spherical and Cylindrical Lenses.

The spherical and cylindrical lenses in all modern trial cases are numbered in what is known as the “metric” or “dioptric” system. The unit of power in this system is a lens having a focal length of one meter (39.37 English inches usually spoken of and figured as 40 inches). Such a lens is known as one diopter (abbreviated 1.00 D.).

As stated above, the focal length of a lens known as one diopter is a meter. Therefore parallel rays of light (and these are the only ones that should be used when measuring lenses), after passing through a $+ 1.00$ D spherical lens are brought to a focus at a point one meter from the lens.

If the lens had twice the refractive power of the unit or was a $+ 2.00$ D Sph., the focal point would be one-half meter distant. If it had four times the power of the unit or was a $+ 4.00$ D Sph., the focal point would be one-fourth of a meter distant. A meter consists of 100 centimeters (abbreviated "cm.") and a centimeter is divided into 10 millimeters (abbreviated "mm."). A meter is therefore 100 cm. or 1,000 mm.

Focal Length of Lenses.

To find the focal length or principal focus (shortest focus) of any dioptric lens in cm., divide 100 by the number of diopters. For example, to ascertain the focal length of a 2.00 D lens divide 100 cm. by 2. Therefore a 2.00 D lens has a focal length of 50 cm. or 500 mm., and a 4.00 D has a focal length of $\frac{1}{4}$ of a meter, or 25 cm. The focal length of a 3.00 D is $\frac{1}{3}$ of a meter, and that of a 10.00 D is $\frac{1}{10}$ of a meter, etc.

Fractional parts of the unit of power, as given above, are expressed in the form of decimals. Thus a lens having one-half the power of the unit would be an 0.50 or 50/100 of the unit. Or if the power be but $\frac{1}{4}$ of the unit it would be written "0.25 D." Or if the power be $3\frac{1}{4}$ times the unit it would be written "3.25 D," etc. The refractive power of spherical and cylindrical lenses is thus expressed in diopters or fractions of a diopter; the smallest fraction in general use being $\frac{1}{8}$ of a D, written "0.12 D." Such a lens represents the interval between the first eight spherical lenses in a trial case containing 37 pairs of spheres.

The interval between 1.00 D and 4.00 D being 0.25 D, and between 4.00 D and 8.00 D the interval is 0.50 D, and between 8.00 D and 14.00 D it is 1.00 D, and between 14.00 and 20.00 D it is 2.00 D. The 20.00 D (written "20. D") being the highest power found in most cases.

Powers of Spherical Lenses.

This makes the powers of spherical lenses, both + and —, found in a trial case containing 37 pairs, as follows: 0.12, 0.25, 0.37, 0.50, 0.62, 0.75, 0.88, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00, 4.50, 5.00, 5.50, 6.00, 6.50, 7.00, 7.50, 8.00, 9.00, 10., 11., 12., 13., 14., 16., 18., and 20. D.

Powers of Cylindrical Lenses.

There should be 24 pairs of each + and — cylinders having the following powers: 0.12, 0.25, 0.37, 0.50, 0.62, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75, 3.00, 3.25, 3.50, 4.00, 4.50, 5.00, 5.50, 6.00, 7.00 and 8.00 D.

Numeration of Prisms.

Prisms are numbered according to their deviating power. One that deviates a ray of light one centimeter for each meter of distance is known as a one prism diopter. Prism diopters are designated by the sign Δ or "P. D." The prism diopter system of numbering prisms is based upon the fact that the decentering of a 1.00 D lens one centimeter produces a deviation of one centimeter for each meter that the ray of light travels after having passed through the lens. The law governing the decentering of lenses to produce prismatic effect, according to Prentice, is as follows: The decentering of a lens one cm. produces as many prism diopters as the lens has refractive diopters. Therefore the decentering of a 5.00 D lens 1 cm. produces five prism diopters (5Δ). Or the decentering of the same lens $\frac{1}{5}$ of a cm. (2 mm.) produces 1 Δ .

Thus the system lends itself admirably to the decentering of lenses for the purpose of producing prismatic effect. This law applies to all lenses, whether they be spheres, cylinders or sphero cylinders. When applied to cylinders the base of the prism must be at right angles to the axis of the cylinder. If the base be 10° from the axis, only $1/9$ of the above prismatic effect is produced. If the base be 30° from the axis, $3/9$ is produced; if it be 60° , $6/9$, etc.

When this rule is applied to sphero cylinders the combined power of the sphere and the cylinder must be counted as a sphere, if the base of the prism is at right angel to the

axis of the cylinder. If the base of the prism and the axis of the cylinder exactly coincide the sphere only should be counted. If the base of the prism is exactly 45° from the axis of the cylinder, all of the sphere and one-half of the cylinder should be counted as a sphere.

Powers of Trial Prisms.

The sixteen prisms in a Trial Case, such as described above, should have the following powers: A pair each of $\frac{1}{2} \Delta$, 1 Δ , 2 Δ and 3 Δ , and one each of 4 Δ , 5 Δ , 6 Δ , 8 Δ , 10 Δ , 12 Δ , 15 Δ and 20 Δ .

The Use of Prisms.

Prisms may be used separately or in combination with spheres or cylinders, or they may be combined with a combination of sphere and cylinder. They are principally used to test the strength of the external ocular muscles. They may also be used to detect malingerers and to exercise certain muscles of the eye. They are prescribed occasionally to offset the effect of diplopia, provided it be due to paralysis of one or more of the external ocular muscles.

When two prisms of the same power are placed one before each eye, with their bases in the same direction, the effect is nil, but if one base is up and the other down, or if both bases are in (toward the nose) or out (toward the temples) the prismatic effect equals the power of both.

Two prisms of the same power, one base in and the other base out, simply neutralize each other, but if the two are not of the same power the prismatic effect is the difference between the two. Some authorities have claimed that the effect of a single 6 Δ before one eye is the same as two 3 Δ placed with the bases in opposite directions, one before each eye. This is not a fact as is generally acknowledged by the best authorities of today and testing for muscular imbalance to indicate where the prism or prisms as well as the base should be placed, is described in the article on the phoropter in this book.

Combining Trial Lenses.

Any number of spherical lenses if placed with their surfaces in contact, or practically so, and their optical centers

coincident will equal a single sphere. For instance a $+ 2.00$ sphere and a $+ 1.00$ sphere will equal a $+ 3.00$ sphere, or a $- 4.00$ sphere and a $- 2.00$ sphere will equal a $- 6.00$ sphere. Or if a $+ 4.00$ sphere and a $- 2.00$ sphere be placed as above, the result would be a $+ 2.00$ sphere, for the $- 2.00$ will neutralize two diopters of the $+ 4.00$, leaving only $+ 2.00$.

In the same manner a $+ 1.00$ sphere and a $- 4.00$ sphere equal a $- 3.00$ sphere.

Cylindrical lenses may also be combined provided their axes lie in exactly the same plane and their surfaces are in contact, or practically so; thus a $+ 2.50$ cylinder and a $+ 1.00$ cylinder, if the axes lie as above, equal a $+ 3.50$ cylinder, or a $- 1.00$ cylinder and a $- 0.50$ cylinder equals a $- 1.50$ cylinder, or a $- 1.00$ cylinder and a $+ 2.00$ cylinder equal a $+ 1.00$ cylinder.

If two cylinders of the same power and character be placed in contact and their axes be at right angles to each other, the resultant lens will be a sphere of the same power as are the cylinders. Example: A $+ 2.00$ Cyl. axis vertical, and a $+ 2.00$ Cyl., axis horizontal, equal a $+ 2.00$ Sph.

If two cylinders of the same character, but not of the same power, be placed with their axes at right angles to each other, the result will be a sphere and a cylinder combined. For instance, if a $+ 2.00$ Cyl. and a $+ 1.00$ Cyl. be placed as above, the result will be a sphere of the power of the weakest cylinder combined with a cylinder the power of which will be the difference between the two cylinders. Therefore the above combination will equal a $+ 1.00$ sphere combined with a $+ 1.00$ Cyl. Such a lens has two diopters of power in one meridian and one diopter in the other.

When combining cylinders their axes should either lie in exactly the same plane or be at right angles to each other. If they so lie the power of the resultant lens may be easily determined. If the axes of any two cylinders lie oblique to each other the power of the resultant lenses may only be determined by an expert. Therefore when combining cylinders always place them with their axes either parallel to each other or exactly at right angles. If two cylinders of oppo-

site character be placed with the axes at right angles to each other, the result will be a simple cylinder, the power of which will equal the combined power of the two. Example: — 1.00 Cyl. axis horizontal and + 1.00 Cyl. axis vertical equal a + 2.00 D. Cyl.

Compound Lenses.

When two or more lenses of different character are combined the resultant lens is known as a "compound." A decentered spherical lens, or one whose optical and geometrical centers do not exactly coincide, is in effect a compound lens, for it is a sphere and a prism combined. Such a lens is known as a "sphero prism." A decentered cylinder is also a compound lens, known as a "cylinder prism." If a sphere and a cylinder be combined the result is a compound lens, known as a "sphero cylinder." A sphero cylinder may also have a prism incorporated with it. Such a lens is known as a "sphero cylinder prism."

Prescription Writing.

When writing formulas or prescriptions (abbreviated "R") the right eye may be indicated by the letter "R" or the letters "O. D.," meaning ocular dexter, and the left eye by the letter "L" or "O. S." meaning ocular sinister. The letters "O. U." indicate both eyes.

For simple spheres the character of the lens should be designated first; then the power, and finally the style. Example: + 1.00 Sph., — 2.00 Sph., etc.

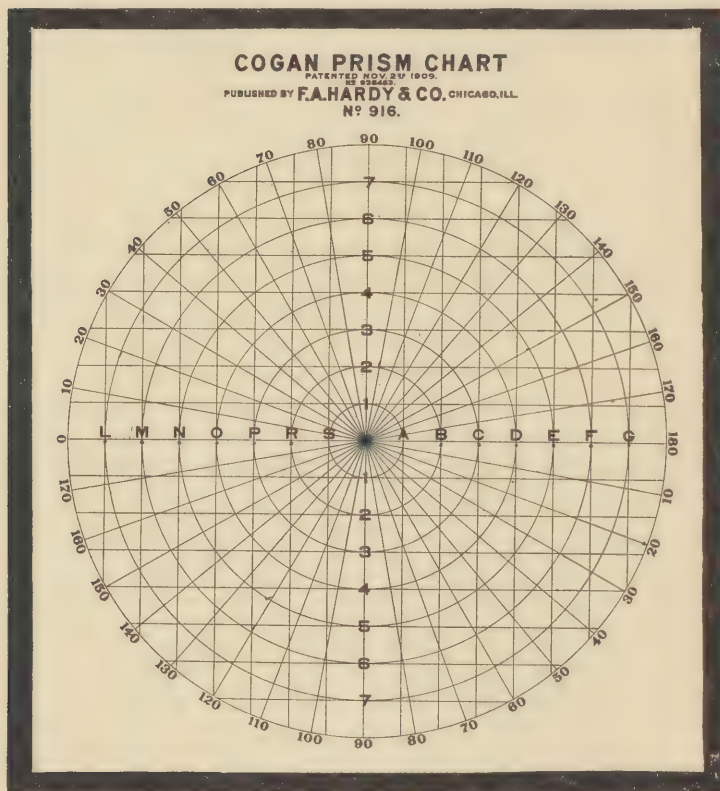
When simple cylinders are desired in addition to the character and power, there should be added the meridian in which to place the axis of the cylinder. Example: + 0.50 Cyl. axis 90., — 2.25 Cyl. axis 180, etc.

When two lenses of different character or power are to be combined the following sign should be used, "⊖." For instance, if a + 2.00 Sph. is to be combined with a + 1.00 Cyl., the R should be written "+ 2.00 Sph. ⊖ + 1.00 Cyl. axis 90," or any meridian desired. The sign "⊖" meaning that the sphere is to be *combined with* the cylinder.

When a prism is prescribed the position of its base must be noted in the R. Example: 1. Δ base in, out, up, or down, or the exact meridian in which the base of the prism is to

be placed may be noted, and this is always necessary if the effect of two prisms with bases in different directions is desired.

For instance, suppose a $3\frac{1}{2} \Delta$ is required for a lateral deviation and a 2Δ for a vertical deviation, the formula



Prism Chart.

would be written " 4Δ base up or down at meridian 30° ." To make the reason for this plain, a prism chart should be consulted.

A prism chart consists of circles and squares, all beginning at the center. Each circle and each square represent one prism diopter (1Δ). Therefore there is a point on the chart that represents a lateral deviation of $3\frac{1}{2}$ prism diopters

($3\frac{1}{2} \Delta$), and a point representing a vertical deviation of 2 prism diopters (2Δ). The distance from the center of the chart to the point where a vertical line drawn through the point representing the lateral deviation, and a horizontal line drawn through the point representing the vertical deviation, cross each other, indicates the strength of the prism required to correct both deviations, and a line drawn from the center of the chart through the point where these lines cross, indicates the meridian in which to place the base of the prism that will act the same as would the two prisms, each placed to correct a certain deviation.

Forms of Ophthalmic Lenses.

Lenses necessarily have two surfaces, each of which must be taken into consideration when we wish to determine their character, power and form, all of which characteristics are important. One surface of a lens may be flat and the other convex spherical or concave spherical. Such lenses are described as "plano convex" or "plano concave," according to their character. Both surfaces may have convex spherical curves, or both may have concave spherical curves. The abbreviation "Dcx.," meaning double convex, indicates the former, and "Dcve.," meaning double concave, indicates the latter.

If one surface has a convex spherical curve and the other has a concave spherical curve, the lens is said to be "*periscopic*."

Periscopic Lenses.

Periscopic lenses, with a single exception, the plano periscopic, have a major and minor curve; the former giving to them their character, and the difference between the two curves fixes their power. Example: One surface $+ 2.25$ spherical and the other $- 1.25$ spherical. The latter curve neutralizes 1.25 of the former, making the power of the lens $+ 1.00$ Sph.

If the major curve is convex the lens is known as a "periscopic convex" and is indicated by the abbreviation "Pcx." If the major curve be concave the lens is a periscopic concave and is indicated by the abbreviation "Pcve." The minor curve

on ordinary periscopic lenses is either $+ 1.25$ or $- 1.25$. The latter being placed upon those having positive (+) power, and the former on those having negative (—) power.

The meaning of the word "*periscopic*" is to peer around or to look in different directions, as when viewing a landscape. The object then in giving a lens the periscopic form is to enlarge and flatten the field, or to give the wearer a larger field of distinct vision.

The concave curve placed on periscopic lenses is always placed next to the eye. It may be of any power desired, or from 1. to 10. or more diopters. If it be 6. diopters the lens is known as a "deep periscopic" or a "meniscus." Such a curve coincides approximately with the arc described by the eye when turning in its orbit for the purpose of viewing objects not located directly in front.

Such a curve placed next the eye enables the wearer to look practically straight through his lenses, whether looking down, as when reading, or looking up sideways, or straight away. In other words, when such lenses are worn the visual line will practically always cut the surface of the lens at right angles. If we look obliquely through a spherical lens there is an astigmatic effect, or the effect of a sphere and a cylinder combined. This causes the retinal images of objects viewed to be more or less distorted. Therefore they are not seen as distinctly as they would be if no distortion took place.

Periscopic lenses are superior to the flat or ordinary styles, because they may be worn closer to the eyes without having the lashes sweep them, and because the cosmic effect is better, and they may be larger than ordinary styles. The periphery of a periscopic lens does not interfere with vision when reading, as much as does the periphery of a lens that does not curve back towards the eye rather than away from it. This curving back makes the distance between the cornea and that portion of the lens through which the wearer looks practically the same, whether looking down, sideways or straight away. This distance is much more nearly preserved when periscopic lenses are worn than when other forms are. The effective power of the lens is varied when the distance between it and the cornea is changed.

A deep — curve is also advantageous when bifocal lenses are prescribed, for it is possible to so place a scale that the wearer looks practically straight through his lenses when reading, as well as straight through them when looking straight away. They also remove, to a great extent, the reflections which annoy many persons wearing ordinary styles.

Periscopic Sphero Cylinders.

Compound lenses may be given the periscopic form by giving one surface a convex or a concave torodial curve, and the other surface a concave or a convex spherical curve. For instance, suppose a $\mathbb{R}$ calls for a $+ 1.00$ Sph. $\subset + 1.00$ Cyl. axis 90° , such a lens if ground as written would be simply a biconvex lens, but if two convex curves are ground upon one surface, and a concave spherical curve ground upon the other surface, this biconvex becomes a periscopic lens. Such lenses are known as "*torics*," getting their name from the shape of one of their surfaces, which is that of a tore, or the shape of an astigmatic cornea. If this form of lens is desired the above $\mathbb{R}$ would be written " $+ 1.00$ Sph. $\subset + 1.00$ Cyl. axis 90 toric," the word "toric" added insuring the periscopic form.

Finished toric lenses have one convex toric surface and one concave spherical surface, or one concave toric surface and one convex spherical surface. When mounting such lenses the concave surface is placed next to the eye.

Compound lenses which have the periscopic form, necessarily have the two curves, which produce the two powers, ground upon one side of the glass, and the curve which produces the least power is known as the base curve. Therefore a $+ 6.00$ base curve would mean that the minor curve was $+ 6.00$, the major curve being enough greater to produce the desired cylindrical power. For instance, if the minor or base curve is $+ 6.00$, and the major curve is $+ 7.00$, the cylinder would be $+ 1.00$, or the difference between the two. The — spherical curve placed upon the other side of the glass may vary in accordance with the amount of spherical power desired. For instance, suppose a $+ 2.00$ Sph. $\subset + 1.50$ Cyl. was desired, and a base curve of $+ 6.00$ was used, the spher-

ical curve would be -4.00 , leaving $+2.00$ in one meridian and $+3.50$ in the other, or $+2.00$ Sph. $\ominus +1.50$ Cyl.

Periscopic Cylinders.

Simple cylinders may be given the periscopic form by giving one surface a toric curve and the other a concave spherical curve, equaling the convex base curve of the toric surface. For instance, if a $+1.25$ Cyl. is desired, the base or minor curve of the toric surface may be $+6.00$ and the major curve $+7.25$, and the spherical curve -6.00 . This latter curve neutralizes all the power of the $+6.00$ base curve, leaving only the $+1.25$ Cyl. The base curve of a concave toric surface is also the minimum curve. Such toric curves are placed upon high power $+$ combinations. The minimum or base curve may be 3., 6. or more diopters.

Convex Sphero Cylinders.

Sphero cylindrical lenses having positive (+) power in all meridians may be given a periscopic effect in one meridian by placing a concave cylindrical curve on one side. For instance, suppose a Rx calls for a $+2.00$ Sph. $\ominus +1.50$ Cyl. axis 90° , by changing the formula to read $+3.50$ Sph. $\ominus -1.50$ Cyl. axis 180° , we have a lens which is optically the same, but of a different form. Such a lens will be periscopic in one meridian, but the power will be unchanged in either meridian; it will still be $+2.00$ Sph. $\ominus +1.50$ Cyl. axis 90° . Such a lens is superior to the biconvex form for the reason that it may be placed closer to the eye, and also because it allows the wearer to look more directly through it when reading.

The vertical meridian, or the meridian which is used the most, and the one in which the lashes sweep, is more or less periscopic, according to the power of the cylinder.

Changing prescriptions for compound or cylindrical lenses from one form to another without changing their power or optical effect is known as transposing.

Transpositions.

The power of a lens depends almost entirely upon the curves given its two surfaces, both of which must be con-

sidered. The dioptric value of a lens then is the result of the combined values of its two surfaces. If both surfaces have spherical curves of the same power, one being convex and the other concave, the result is a periscopic lens of no power or a plano periscopic. But if one curve has greater power than its opposing curve, the result is a lens having power. If the convex curve has the greatest power the lens is a positive one. On the other hand, if the concave curve has the greatest power the lens is a negative one. These convex (+) and concave (—) curves are known as dioptric curves. They may be measured with a Sphereometer or Lens Measure quite accurately whether they be spherical + or —, or cylindrical + or —, or plano.

If both surfaces are concave or convex spherical the value of the lens is the algebraic sum of the two surfaces. Example: + 2.00 Sph. on each side equal + 4.00 sphere, or — 3.00 Sph. on each side equal — 6.00. If one surface has a spherical curve and the other has a cylindrical curve, they cannot be added together for the reason that the character of the two are not the same, one being a sphere and the other a cylinder, each of which must be expressed in the formula. Example: + 2.00 Sph. $\subset$ + 1.00 Cyl. axis 90°. A transposition of this formula would be + 3.00 Sph. $\subset$ — 1.00 Cyl. axis 180. In this transposition we have used the following rule, which may be used for all + on + or — on — combinations:

Add to the power of the sphere the power of the cylinder; change the sign of the cylinder and move its axis 90°.

Thus a + 2.00 and a + 1.00 curve equal a + 3.00 curve, which is the power of the lens in the meridian of its greatest refraction. Therefore the power of the new sphere must be + 3.00, but + 3.00 is 1.00 D too strong for the other meridian, therefore a — cylindrical curve of 1.00 D must be placed upon the other surface. The axis of the cylinder being moved 90° leaves the meridians of least and greatest power in the same position that the original formula placed them.

Rules for Transposing.

Rule 1. For combination of + spheres on + cylinders or — spheres on — cylinders.

For the new sphere add to the power of the sphere the power of the cylinder. Change the sign of the cylinder and move axis 90° .

Examples—

+ 2.00 Sph. $\ominus$ + 1.00 Cyl. axis 90, equals + 3.00 Sph.
 $\ominus$ — 1.00 Cyl. axis 180.

— 1.50 Sph. $\ominus$ — 0.75 Cyl. axis 180, equals — 2.25 Sph.
 $\ominus$ + 0.75 Cyl. axis 90.

Rule 2. For combinations of + spheres on — cylinders or — spheres on + cylinders subtract the power of the weaker from that of the stronger surface and use the result for your sphere, which should have the sign of the strongest surface.

Use same power of cylinder for the new cylinder, but change sign and move axis 90° . If both surfaces measure the same, except one being spherical and the other cylindrical, use either for your sphere.

Examples—

+ 2.00 Sph. $\ominus$ — 1.00 Cyl. axis 20, equals + 1.00 Sph.
 $\ominus$ + 1.00 Cyl. axis 110.

+ 1.00 Sph. $\ominus$ — 1.50 Cyl. axis 180, equals — 0.50 Sph.
 $\ominus$ + 1.50 Cyl. axis 90.

— 2.00 Sph. $\ominus$ + 0.75 Cyl. axis 90, equals — 1.25 Sph.
 $\ominus$ — 0.75 Cyl. axis 180.

— 0.75 Sph. $\ominus$ + 2.25 Cyl. axis 80, equals — 1.50 Sph.
 $\ominus$ — 2.25 Cyl. axis 170.

Rule 3. For plano cylinders + or — use a sphere of the same power and sign as the cylinder. Change sign of cylinder and move axis 90° .

Examples—

+ 1.75 Cyl. axis 90 equals + 1.75 Sph. $\ominus$ — 1.75 Cyl. axis 180.

— 1.25 Cyl. axis 160 equals — 1.25 Sph. $\ominus$ + 1.25 Cyl. axis 70.

Rule 4. For crossed cylinder combinations, axes at right angles to each other + Cyl. on + Cyl. or — Cyl. on — Cyl.

Use the power and sign of the weakest cylinder for your sphere. Use the difference between the two cylinders for your cylinder. Use axis and sign of the strongest cylinder.

Examples—

+ 1.25 Cyl. axis 90 $\ominus$ + 2.25 Cyl. axis 180 equals + 1.25 Sph. $\ominus$ + 1.00 Cyl. axis 180.

+ 2.50 Cyl. axis 70 $\ominus$ + 1.25 Cyl. axis 160 equals + 1.25 Sph. $\ominus$ + 1.25 Cyl. axis 70.

— 0.25 Cyl. axis 90 $\ominus$ — 1.00 Cyl. axis 180 equals — 0.25 Sph. $\ominus$ — 0.75 Cyl. axis 180.

— 2.00 Cyl. axis 45 $\ominus$ — 1.25 Cyl. axis 135 equals — 1.25 Sph. $\ominus$ — 0.75 Cyl. axis 45.

If both cylinders are of the same power and sign the result is a sphere.

Rule 5. For crossed cylinders + on — or — on + combinations, axes at right angles.

Use power and sign of one cylinder for your sphere. Use the combined power of both cylinders for your cylinder. Use sign and axis of cylinder not used for the sphere.

Examples—

+ 2.25 Cyl. axis 1.00 $\ominus$ — 2.75 Cyl. axis 10 equals + 2.25 Sph. $\ominus$ — 5.00 Cyl. axis 10 or — 2.75 Sph. $\ominus$ + 5.00 Cyl. axis 100.

Rule 6. For moving axis.

If the meridian be 90 or less add 90; if it be 90 or more subtract 90.

Transposing by Means of a Cross.

We may represent the two principal meridians of a cylindrical or a sphero-cylindrical lens, or the principal meridians of an astigmatic eye by means of a cross, the lines of which are drawn at right angles to each other, and in the meridians representing those of least and greatest power. If these meridians are vertical and horizontal, the lines of the cross would lie in meridians 90° and 180°, or if the meridians are oblique, like 45 and 135, they would be drawn in those meridians, or they may be drawn in any two meridians which are exactly 90° apart.

Each line of the cross represents a cylindrical lens, the power and character of which, as well as the meridians, may

be noted on the lines as shown in the following diagrams. If both the cylinders are of the same power and character, as shown in Diagram A, the result would be a spherical lens of the same power and character as the cylinders noted, but if the powers are not the same, the result would be either a plano cylinder, as shown in Diagram C, or a sphero-cylinder, as shown in Diagram B.

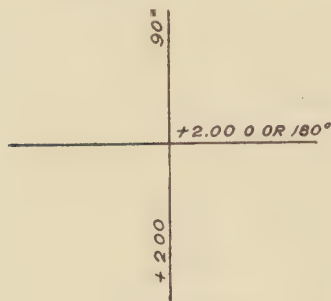


Diagram A

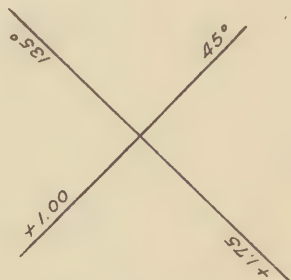


Diagram B



Diagram C

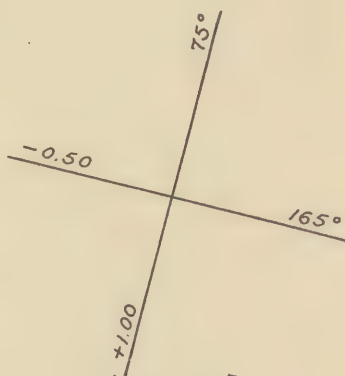


Diagram D

In the lens represented in Diagram B the cylinders are not of the same power. Therefore the lens becomes a compound, or one having different powers in different meridians.

In transposing such a lens, the weakest cylinder is taken for the sphere, and the algebraic difference between the two powers for the cylinder, and the meridian having the least power for the axis of the cylinder.

According to this rule, the formula for the lens represented in Diagram B would be $+ 1.00 \text{ Sph. } \ominus + 0.75 \text{ Cyl. axis } 45^\circ$, or if transposed according to Rule 1, $+ 1.75 \text{ Sph. } \ominus - 0.75 \text{ Cyl. axis } 135$.

As stated above, in these cross line diagrams, the lens represented by each line of the cross is a cylinder superimposed over another cylinder, the axis of which is at right angles to the axis of the other.

The location of the axis of one cylinder fixes the position of the lines in regard to the meridians. In Diagram D the lens represented is a cross cylinder having $- 0.50 \text{ D}$ power in one meridian and $+ 1.00 \text{ D}$ power in the other. Such a lens may be made in three different ways. First, we may grind a $-$ cylinder of 0.50 on one side and a $+ 1.00 \text{ D}$ cylinder on the other, the axis of the plus cylinder to be at right angles to the axis of the $-$ cylinder. Second, we may grind a $- 0.50$ sphere on one side and a $+ 1.50$ cylinder on the other; or third, we may grind a $+ 1.00$ sphere on one side and a $- 1.50$ cylinder on the other. The optical effect of these three lenses is the same, but either of the two latter styles is to be preferred, for the reason that it is difficult to grind two cylinders with their axes exactly at right angles to each other.

Retinoscopic Findings.

Retinoscopic findings may be noted on the lines of a cross as described above, and then transposed according to the above rules, the power and character required in each meridian, as well as the meridians themselves, being noted on the lines of the cross.

Character, Form and Power of Lenses.

Every optometrist, in fact everyone who makes a business of adjusting spectacles or eye glasses, will have many patients come to him wearing glasses the character, form and power of which must be determined. He will also be called upon to duplicate many broken lenses and to match whole ones, and to name prices for doing this work. These prices must necessarily vary greatly, according to the style, power, shape, size and color of the lenses. Therefore some ready and re-

liable means of thoroughly analyzing such lenses is a necessity. Happily everyone possessing a reliable Trial Case and a Spherometer or Lens Measure has such means.

The character of a lens may be determined by moving it before your eye and noting the apparent movement of objects seen through it. If this apparent movement is in the opposite direction to the movement of the lens it is convex (+), but if the apparent motion is with the movement of the lens it is concave.

The form of a lens may be best determined with a Spherometer or Lens Measure (See Fig. XIII). This instrument ap-

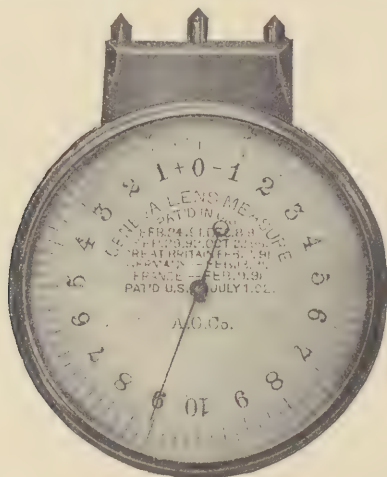


FIG. XIII.

GENEVA LENS MEASURE.

plied to the surface of a lens enables one to determine whether such surfaces are spherical or cylindrical, and whether convex or concave, and also the power of the curves.

The refracting power of many lenses may also be determined approximately by the use of this instrument. There are, however, many lenses which cannot be measured, even approximately, with it. For instance, Kryptok and Opifex bifocal lenses or lenses made from glass of unknown index or those made of pebble, cannot be measured with it, even approximately. Such lenses must be measured by neutralizing them with lenses of known power.

Measuring Lenses by Neutralization.

The character of a lens depends upon the curves given its surface. If the master curve be convex the lens is a positive one. If the master curve be concave the lens is a negative one. The form of a lens may be spherical or cylindrical; or it may be both spherical and cylindrical. It may also be sphero-toric in form.

In addition to the above forms there is what is known as plano lenses and prisms. The former has flat surfaces or curved surfaces which lie parallel to each other. The latter form also has flat surfaces, but they do not lie parallel to each other. A prism, therefore, is made wedge shape; its thick edge is spoken of as its base and its thin edge as its apex

All refracting lenses, whether spherical, cylindrical, sphero-cylindrical (or of whatever form) are practically made up of prisms. These all, therefore, have prismatic effect. This causes objects viewed through them to be displaced unless the object seen through the optical center or optical axis of the lens. If a convex lens be moved from side to side in front of an eye, the object viewed through it will appear to move, and this movement will be in the opposite direction to the movement of the lens. If the lens be concave the apparent motion will be with the lens. If the lens be moved up the object appears to move up, and vice versa. If the lens be a sphere the movement will be the same in all meridians. If it be a cylinder there will be no movement in the meridian of its axis, but there will be movement in all other meridians. If it be a sphero-cylinder the movement will be greater in one meridian than it is in another. These movements, therefore, indicate both the character and kind of the lens, and they also afford a ready means of determining its strength.

A plano lens causes no apparent displacement. Therefore no movement takes place when such a lens is moved as described above. If we place two spherical lenses of the same power and of opposite sign in contact with each other, with their curved surfaces together and their optical centers coincident, a plano lens will be the result. Therefore when these lenses so held are moved in front of an eye no apparent motion

will be noted, the negative refraction of one lens having exactly neutralized the positive refraction of the other. If the power of one of these lenses be known the power of the other is apparent. It is essential, however, that the above conditions, viz., optical centers coincident and surfaces in contact, should be established.

It is apparent that the above conditions cannot be met unless one of the two lenses be plano concave and the other plano convex; and that their curved surfaces are together. The resulting plano lens will have flat surfaces. A biconvex lens of four diopters placed between two plano concave lenses of two diopters each would also produce a plano lens with flat surfaces; but one such biconvex and biconcave would not exactly meet the above conditions, because the outer surfaces would not be plano.

It is not possible in actual practice to always meet the above ideal conditions, but they must be practically met if exact results are to be obtained.

When neutralizing a lens for the purpose of obtaining its power as few lenses as possible should be used; and convex and concave surfaces, whether spherical or cylindrical, should be placed together. The axes of neutralizing cylinders should lie in exactly the same plane.

The low power (0.12 to 8.00-D) spherical lenses of opposite sign and equal strength will practically neutralize each other, even if their positions are not ideal, but high power lenses, or lenses of low power but having sharp curves, like toric or meniscus lenses, should be neutralized with lenses having curves as near like those being neutralized as possible. Plano concave and plano convex are the most practical forms to be had for neutralizing purposes.

When wishing to determine the power and character of a lens by neutralization, first look through the lens at an object some distance off and note the apparent movement of the object viewed. If when the lens is moved up and down and sideways the movement is in the opposite direction the lens is convex (+). If the movement is with the lens it is concave (—). If there is movement except in one meridian it is a cylinder; and the meridian in which no movement occurs is

its axis. If there be no movement it is either plano or a prism.

The extent of these movements indicates the power. Low powers like 0.12 produce but little motion. If the movement is against we select a concave lens from our Trial Case, and holding the two together move as before. If there is still motion against, a stronger curve must be chosen, if with, a weaker one. A lens that stops all motion has the same power as the one it neutralized. If the lens be a sphero-cylinder the motion will be stopped in the meridian having the least



Diagram E.



Diagram F.

power by a lens that represents the spherical element, and in the opposite meridian by another. The difference between the power of these two lenses represents the cylindrical element.

When neutralizing cylinders or sphero-cylinders the axis of the cylinder should be dotted to enable the operator to move the lens exactly in the plane of its principal meridians. If we view a straight line through a cylinder or a sphero-cylinder and rotate the lens in its plane, that portion of the line seen through the lens will be tilted more or less, depending upon the extent of rotation and the power of the cylinder. The line will appear straight or continuous when the axis of the cylinder lies either in the same plane as the line or at right angles to it. (See Diagrams E and F.) By this means the principal meridians of a sphero-cylinder or the axis of a simple cylinder may be located and dotted. The lens should be held midway between the eye and the line, which should be at arm's length.

The axis of the cylinder may be located approximately, but not always accurately, by a Lens Measure. If in place of a single line we draw two lines at right angles to each other we may locate the optical center of the lens as well as the axis. To do this we move the lens about and rotate it until the lines forming the cross are continuous and unbroken. When both lines are straight or unbroken the eye (one eye should be covered), that views them is looking through the optical center, which should be dotted. If the lens is dotted correctly and the dot is not at the geometrical center of the lens, there is a prism incorporated in it. A prism displaces an object in a single direction,—the displacement being in the direction of its apex. Prisms of like power neutralize each other when the base of one overlies the apex of the other. Therefore when neutralizing a prism place the base of the neutralizing prism in the direction of the displaced image. The prism that places the optical center at the geometrical center represents the prism incorporated in the lens.

In neutralizing lenses stronger than 8.00 D, unless plano spherical test lenses are used, there will be more or less aberration at the edges. This may be stopped by placing between the lenses a thin piece of black paper with a hole about one centimeter in diameter cut in it. By this means the center of the lens may be neutralized.

When neutralizing toric lenses the test lens should be placed on the outer convex side. If placed on the inside there will be quite a space between the lenses at the center, making it impossible to obtain good results.

Two cylinders of like power and opposite sign will not neutralize each other unless their axes lie in exactly the same plane. The power of such lenses may be more easily obtained if spherical lenses are used and the cylinder moved in the meridian at right angles to its axis. The lens to be neutralized and the neutralizing lens or lenses should be placed in a trial frame or in cells having meridian scales. Such a cell is shown on page 88.

Our Eyes.

Eyes have been called the "windows of the soul," and why? It is probable because the soul looks out through them

and observes the beauties of nature, the perfect blending of her colors, the changing views of hill and dale as the seasons come and go, and the myriads of lights in the windows of heaven,—and do not these views enable us to get a glimpse, as it were, through the soul's eye of the Creator of these, to us, most beautiful pictures.

But how do the eyes reveal to our minds or our souls the beauties of the landscape and the majesty of the heavens? It is said that the refracting media of a normal eye, acting like a strong convex lens, converges the light rays that enter it, so that they are brought to a focus upon its retina, and that there is then an image or picture of the object from which the light waves came produced there, and that this picture is transmitted by the nerve fibers which compose the retina, to the brain, and that the brain, if it be normal, transmits it to the mind or to the soul, and we see.

All this is probably true, and if so what is the retina like, or what may we liken it to. It is said to be made up of uncountable fibers or nerves, each one of which leads to the brain, like each wire of a telephone system leads to a central office. Or perhaps the web or net of a spider is a better illustration of the retina,—the purpose of the net being the catching of insects and that of the retina the catching of images. From what is known of the web and of the retina, they seem to be much alike. The spider in building his net runs lines from a central point out in every direction, attaching them to whatever suits his purpose. These lines usually form a sort of cornucopia or horn of plenty shape. After these radiating lines are all in place he weaves into them circular ones. These he places very close together at the center, but as he gets away from the center he places them farther and farther apart, so that the meshes of his net become larger and larger as the periphery is approached.

When this cunning little creature has his net complete he hides himself back in the horn, with his feet resting on the radiating lines, so that if one of them be touched he knows exactly which one it is, and therefore exactly where to go to secure his catch.

Now these radiating lines of the spider's web represent what is known as the rods, and the circular ones represent what is known as the cones of the retina, and these rods and cones seem to occupy much the same relation to each other as do the lines in the spider's net. The cones are very close together at the fovea centralis, known as the "macula," but are farther and farther apart as they spread out over the interior part of the anterior surface of the eye. Because of the cones being very close together at the macula, vision is the most acute at that point. For this reason we instinctively turn our eyes so as to look directly at an object that we wish to see distinctly, for when so looking the light from the object falls upon the macula. But in order to see clearly these rays of light must be brought to an exact focus, so as to form a sharply defined image or picture.

Rays of light in nature are always divergent, and the amount of this divergence is governed entirely by the distance that it has traveled after leaving its source, an illuminated point. At $1/10$ of a meter from an illuminated point the divergence amounts to exactly 10 diopters; at $1/4$ of a meter it amounts to 4 diopters; at 1 meter it amounts to 1 diopter. At a distance of 6 meters they are for all ordinary optical purposes considered as being parallel, yet they are actually $1/6$ of a diopter divergent. A 2.00 D convex lens placed 1 meter from the source of light will bring it to a focus 1 meter on the other side of the lens; 1 diopter of its power having been used to overcome divergence, and the other diopter to converge it to a point.

The illuminated point from which the light proceeds is called the "radiant," and the point to which they converge, the "focus." These two points are known as "conjugate" points; they are interchangeable one with the other. If the radiant be at the principal focus (shortest possible focus) of a lens, the rays of light from it will immerge from the lens as parallel rays. If the radiant be beyond the principal focus of a lens the immergent rays will be convergent and will be brought to a focus beyond the principal focus of the lens. If the radiant be within or nearer to a lens than its principal focus, the rays

immersing from it will still be divergent, but less so than they were before entering it. Such rays would never come to a focus.

Emmetropia.

The above being true, if the eye acts like a strong convex lens, and the radiant be a point on the retina, and the retina be at the principal focus of the eye, the rays of light from points on it after immersing from the eye, will be parallel. Such an eye is said to be "emmetropic." The refraction of an emmetropic eye being consistent with its length through its visual axis (length from cornea to macula) cannot be improved with lenses. It is then, so far as refraction goes, the ideal eye and the goal in refraction work.

Hyperopia.

If the radiant (retinal point) be within the principal focus of an eye, the rays immersing from it will be divergent, such an eye is deficient in refracting power, and is said to be "hyperopic"—often spoken of as being far-sighted. The refraction of a hyperopic eye (a short eye) being deficient, may be added to by placing in front of it convex spherical lenses, and the lens that causes the rays immersing from the eye to be parallel is the measure of its hyperopia. Such a lens makes a hyperopic eye artificially emmetropic.

Myopia.

If the radiant (retinal point) be beyond the principal focus of an eye, the immersing rays will be convergent, such an eye has excessive refraction and is said to be "myopic," commonly spoken of as near-sighted. The excessive refraction of a myopic eye (a long eye) may be neutralized by placing in front of it concave spherical lenses, and the lens that neutralizes only the excessive refraction is the measure of its myopia. Such lenses placed before a myopic eye renders it artificially emmetropic.

Ametropia.

Any variation from an emmetropic condition is known as "ametropia." If the "ametropia" can be corrected with spherical lenses the condition is known as "axial ametropia."

When a refractive error exists that cannot be corrected with spherical lenses, the ametropia is known as "curvature ametropia." Such ametropia is commonly called "*astigmatism*."

Astigmatism.

Curvature ametropia is that condition in which the refracting media of the eye does not refract or bend the rays of light that enter it equally in all meridians; the result being that all the rays are not focused at a single point, as they would be if emmetropia or axial ametropia existed. There are two varieties of astigmatism, one known as "regular" and the other as "irregular." The latter variety cannot be wholly corrected with lenses, but the former may be.

In the regular variety there exists two principal refracting meridians lying at right angles to each other. The difference in refracting power of these two meridians is the amount of the astigmatic error. One of these principal meridians may be emmetropic and the other ametropic. Such an error is known as "*simple astigmatism*."

If the faulty meridian be hyperopic the error is called "simple hyperopic astigmatism," but if it be myopic it is known as "*simple myopic astigmatism*."

When both principal meridians are hyperopic, one being more so than the other, the error is known as "*compound hyperopic astigmatism*." If both principal meridians are myopic, but different in amounts, the error is called "*compound myopic astigmatism*."

If the macula region of the retina lies between the two focal points, one meridian must be myopic and the other hyperopic. This condition is known as "*Mixed astigmatism*." The simple varieties may be corrected with cylindrical lenses, but the compound varieties require compound lenses for their correction or a sphere and a cylinder.

Astigmatic errors are the most difficult ones to measure on account of the difficulty in locating the principal meridians, commonly called "axes."

From what has been said about the laws of light and its refraction, it will be seen that the refracting media of an

eye cannot always act exactly like a strong convex spherical lens, for if it did only rays of light that had traveled a certain distance would be sharply focused upon its retina.

Therefore, if rays diverging from points on objects situated at different distances from the eye must be brought to a sharp focus on its retina, the eye must adjust its refraction to suit these different distances. For instance, an emmetropic eye, or one adjusted for parallel rays, wishing to see distinctly an object located one meter distant, must increase its refraction one diopter, for rays diverging from points one meter distant are divergent to that extent, and this divergence must be overcome.

If the object be only $\frac{1}{4}$ of a meter distant, then 4. D represents the divergence that must be overcome; if only $\frac{1}{10}$ of a meter, then 10. D must be overcome; if $\frac{1}{6}$ of a meter than 6. D, etc.

Accommodation.

The power to increase the refraction of an eye is called "accommodation" (abbreviated "Ac."), for the reason that an eye that has this power accommodates itself to rays differing in amounts of divergence. The amount of this power possessed by normal eyes varies according to the age and physical conditions of the patient. At the age of 10 it amounts to 14 diopters; at 15 to 12 diopters; at 20 it amounts to 10 diopters, and this amount enables an emmetropic eye to focus sharply upon its retina rays of light diverging from points on an object situated only 10 cm. from it. Accommodation therefore increases the refraction of the eye and adapts it to near objects. Accommodation is brought about by a change in the shape of the crystalline lens, due to contraction of the ciliary muscle, which makes it more convex.

Punctum Proximum.

The nearest point for which an eye can accommodate is known as its "punctum proximum" (abbreviated "P.p.).

As stated above, an emmetropic or normal eye at the age of 20 possesses 10. diopters of his power; the near point of distinct vision (P.p.) is then 10 cm. distant. At the age of 30

the accommodation has decreased to $7\frac{1}{2}$ diopters; the P.p. has therefore receded to $13\frac{1}{2}$ cm. At the age of 40 the accommodation amounts to but 5 diopters; the P.p. then has receded to 20 cm. At the age of 50 there remains but $2\frac{1}{2}$ diopters of this power; the P.p. having receded to 40 cm. At the age of 60 very little accommodation is present; at least very little can be used for sustained vision, the P.p. having at this age receded practically to "infinity." At the age of 60 then, the near and the far point of distant vision occupy practically the same position.

It will be noticed by the above that between the ages of 20 and 60, or in 40 years, practically 10 diopters of this most valuable power has been lost. It will also be noted that the loss occurs practically at the rate of $\frac{1}{4}$ of a diopter each year. The loss of this power is so universal and so regular that it is possible to name the age of patients between the ages of 20 and 60 quite accurately, provided, of course, that the accommodation has been measured accurately, and that the patient is in normal physical condition. The accommodating power of all eyes, whether they be Emmetropic, Hyperopic or Myopic, for any given age between 10 and 60 is practically the same, but the near point or P.p. varies according to the refraction of the eye when in a state of rest or when the ciliary muscle is entirely relaxed.

The following table shows very closely the near point, or P.p.; also the accommodating power of emmetropic eyes at different ages. The near point being given in centimeters and fractions and the accommodating power in diopters:

Age.	Ac.	Cm.	Age.	Ac.	Cm.
10	14 D	7.1	36	6	16.6
12	13	7.7	40	5	20.0
14	12	8.3	44	4	25.0
17	11	9.1	48	3	33.3
20	10	10.0	52	2	50.
24	9	11.1	56	1	100.
28	8	12.5	60	.50	200.
32	7	14.3	64	.00	.00

Punctum Remotum.

When the accommodation is at rest (ciliary muscle entirely relaxed) the eye is adjusted for its remote point of distinct vision, known as its "punctum remotum" (abbreviated P.r.).

The punctum remotum of an emmetropic eye is at infinity (designated by the sign " ∞ ") because parallel rays, or those from distant objects, are brought to a focus upon its retina without accommodation. But the remote point of a myopic eye is always at a definite distance inside of infinity. A myopic eye is then always positive; the immergent rays being convergent. If 2. D of myopia exists the remote point is distant from the eye, the focal length of a 2. D lens, or 50 cm. If 4. D is present the remote point is 10 cm. distant, or the focal length of a 10. D. lens, etc.

The remote point of a hyperopic eye is always negative; the immergent rays being divergent. To locate the P.r. or remote point of such an eye we must trace these divergent rays back to a point back of the retina from which they seem to have come. We might say that the remote point of an eye that is 2. D. hyperopic is 2. D. beyond infinity, for it requires a + 2. D. lens, or its equivalent in accommodation, to focus parallel rays upon its retina. If 4. D. of hyperopia is present the rays emerging from the eye would seem to have come from a point 10 cm. back of the retina. It will be seen by the above that the remote points must vary greatly, according to the refraction of the eyes when in a state of rest (accommodation suspended). This being true, the proximum points must also vary greatly.

The proximum point of a myopic eye is always nearer the eye than the proximum point of an emmetropic eye of the same age, and the proximum point of a hyperopic eye must be further from the eye than would be the proximum point of an emmetropic eye of the same age.

It will be seen by the above that the position of the near point, or punctum proximum, should always be carefully ascertained, for the reason that this point when compared with the patient's age indicates not only the character of the

refractive error, but also approximately its amount. We may express in diopters or in focal lengths of lenses both the remote and the proximum points of an eye, as well as its accommodating power.

For instance, suppose the remote point of a myopic eye be distant 50 cm., this being the focal length of a 2 D. lens, we may record the P.r. as -2 , or whatever power the lens may be that represents the myopia present. Again, suppose the P.p. of this same eye is 10 cm. distant from it this distance is the focal length of a 10 D lens. Therefore the P.p. of such an eye may be recorded as -10 and as the accommodating power is always the difference in diopters between the remote and proximum points it may be recorded as 8. D. A record then of the above eye would be as follows: P.r. -2 , P.p. -10 , A.c. 8. D.

If the above eye were hyperopic 2. D. instead of myopic and had the same accommodating power, the record would be P.r. $+2$, P.p. -6 , accommodation 8. D. If the eye were emmetropic and had the same amount of accommodating power the record would be as follows: P.r. ∞ P.p. -8 , A.c. 8. D. If the age of the patient be included in the records they will afford interesting and instructive reading, especially to those who have memorized (as recommended) the age and accommodation tables. At the age of 20 the P.r. of a myope of 4. D. and the P.p. of a hyperope of 6. D. occupy practically the same position in front of the eye, both being 25 centimeters distant from it.

Range of Vision.

A myope of 4. D. sees nothing distinctly beyond 25 cm., but by accommodating may see distinctly objects nearer to the eye than 25 cm.

If the myope of 4. D. puts in force 10. D. of accommodation they may see distinctly objects as near the eye as the focal length of a 14. D. lens or the focal length of any lens that represents both the myopia present and the accommodation put in force. For instance, if 6. D. of myopia is present and they can accommodate 8. D. they can see distinctly objects as near the eye as the focal length of a 14. D. lens, which is practically 7 cm. As a consequence the range of distinct vision in

such cases is limited to objects located between 7 and 25 cm. from the eye.

The hyperope cannot see distinctly at any distance without putting in force some accommodation, therefore his range when the accommodation is at rest is much more limited than is the range of the myope, but when they put in force sufficient accommodation to overcome their hyperopia they will be able to see distinctly all objects beyond 6 meters and by enforcing sufficient accommodation to overcome the divergence of the rays that proceed from nearby objects they will be able to see distinctly objects nearer the eye than six meters. For instance, a hyperope of 3. diopters must put in force 3 D. of accommodation to see distant objects clearly, and if they wish to see clearly objects 10 cm. from the eye they must put in force 13 diopters of accommodation; 3. diopters of this 13 is to overcome their hyperopia and 10. D. more for the near point. Thus it will be seen that the range of distinct vision is limited in both myopes and hyperopes and that it is more limited in hyperopia than in myopia, provided no accommodation is put in force or when the A.c. is at rest.

Accommodation then increases the range of both myopes and hyperopes, but it is of the greatest value to the hyperope, for they cannot see clearly at any distance without putting in force some accommodation.

SUBJECTIVE EYE TESTING.

When measuring the refraction of an eye by the subjective method, or with trial lenses, a certain routine should be persistently followed.

The patient should be comfortably seated at the fitting table facing the test charts, which should be hung flat on the wall six meters distant and well illuminated; the illuminating lights being screened from the patient's eyes. The six meter letters



on the chart should be on a level with the patient's head. If six meters is not obtainable a mirror and reverse test letters should be used.

The fitting table should be narrow and quite long. One 14 by 50 inches is a popular size. It should have one or more drawers to hold a few tools, R blanks, etc. The operator should be seated to the left of and facing the patient. In this position, with the trial case on the table at his right, everything will be convenient.

The patients should be allowed to recite their eye troubles and to tell why they desire glasses and for what particular purpose. Such a recital often gives a refractionist a clue to

the existing conditions. Something may also be gained by noting the general appearance of the patient, remembering that a small eye indicates hyperopia, while a large and prominent one indicates myopia. Large pupils also indicate myopia, while small ones denote hyperopia. If the patient's features are not symmetrical astigmatism may be suspected.

If the patient is unable to see distant objects, but sees those close at hand quite well, myopia is indicated, but should they see distant objects well but have difficulty in reading or sewing, especially by artificial light, hyperopia is indicated. Headache is also a marked symptom of hyperopia or of hyperopic astigmatism. If both near and distant vision is defective, we may suspect that it is due to some structural or pathological condition of the eyes themselves. To differentiate between such a condition and a refractive error which may be corrected with suitable lenses we should resort to the pin hole test.

The pin hole disc should be placed in the trial frame, which should be adjusted so that the perforation comes at the center of the pupil. Only a small pencil of rays will then pass through the pin hole and through the axis of the refracting system of the eye. Such rays will form a sharply defined image or picture upon the retina for all distances. If then the pin hole improves vision, the refracting system of the eye is at fault. On the other hand if no improvement is noted we may suspect that the transparency of the media or the retinal sensibility is defective.

If the pin hole disc improves vision but lenses do not materially do so, irregular astigmatism may be suspected. To differentiate between the regular and the irregular varieties of this error we must resort to an Ophthalmometer or to a Placidoscope. The former may be used to advantage at the beginning of the test.

When making the pin hole test the type must be well illuminated, for at best but little light reaches the eye. Therefore the adjustment of the perforation must be correct. Each eye must be examined separately; the other one being covered with a blank disc. It is a good plan for the refractionist to obtain all the information possible regarding any particular case before placing any lenses before the patient's eyes, and in

order to do this they should note on a blank suitable for the purpose the patient's age, address, sex, occupation, and whether or not glasses have ever been worn, and if so for how long; also any special history of the case that the patient may offer.

It may not be possible to correct the ametropia with trial lenses so that the visual acuity will equal that shown by the pin hole test, but it should be nearly the same.

The punctum proximum, or near point of distinct vision, should also be carefully measured and recorded. This may be obtained as described on page 147 under the heading of locating and recording the near point. The near point of distinct vision often gives striking evidence as to where the remote point is, or ought to be. In other words whether myopia or hyperopia exists and its probable extent. For instance, if the near point is nearer to the eye than the age of the patient indicates that it should be, myopia is indicated. On the other hand if the near point is further from the eye than it should be for the patient's age hyperopia is indicated. The near point may indicate partial paralysis of the accommodation. This is especially true in cases of children who have suffered from diphtheria or scarlet fever or some other depressing disease. Such cases might be overlooked (which would be a sad mistake) if the punctum proximum (P. p.) is not ascertained. If the P. p. is not the same in both eyes it should also be known and recorded.

The table of near points of emmetropic eyes on page 48 should be as familiar to the optometrist or oculist as the dioptric numbers of the lens in his trial case. The amount of accommodating power present at different ages should also be committed to memory. The refractionist cannot place too high a value upon the knowledge obtained by measuring the range or amplitude of accommodation, and comparing it with the age of the patient, a few of whom will possibly not name the correct figure, but a careful observer will be governed by the evidence given by his tests rather than by the statements of such patients. The range or amplitude of accommodation is best measured with the Punctunreter, see page 110.

The visual acuity of each eye taken separately or with the other covered with the opaque disc should also be recorded

both with and without correcting lenses. The vision shown by hyperopes often exceeds the standard for normal, but this, however, is no proof that hyperopia is not present, for the patient may unconsciously put in force his accommodation, which amounts to exactly the same thing as placing convex spherical lenses before his eyes. In fact hyperopes naturally and habitually use their accommodation for all distances, for they cannot see distinctly without using it. Therefore accommodation finally becomes a persistent or fixed habit with them. The distant vision of myopes is always more or less defective and any accommodation that they put in force only increases their myopia. Myopes then only use their accommodation when viewing objects nearer to their eyes than their punctum remotum.

The accommodation being one of the greatest factors in refraction work should be studied most carefully. It is not the purpose of this work to show how it is accomplished; in fact it is not known absolutely how it is brought about, but to make clear the reason for and the value of this power, and to show how it effects the refraction of the eye, and therefore the work of the oculist or optometrist.

The accommodation is generally considered, and rightly so, the refractionist's antagonist, for it must be taken into account in practically every case refracted; it therefore should be carefully studied from every angle. There are many refractionists who deem it best to put it out of business, as it were, for the time being. They instill into the eyes a cycloplegic, which renders the ciliary muscle unable, for the time being, to perform its natural function,—that of increasing the refraction of the eye and adjusting it for points nearer than infinity. There are others who deem it best to try to control the action of the ciliary muscle by producing an artificial myopic condition, for in this condition the tendency of the eye to accommodate is not only checked, but is induced to relax because vision is improved as relaxation takes place.

The advocates of the former method believe that there is a spasmodic action of the ciliary muscle that will not relax except under the influence of a cycloplegic. It is a fact, however, that the ciliary muscle, under normal conditions, is never

so thoroughly relaxed as when under the influence of drugs. Therefore the lenses chosen under such conditions are practically always stronger than can or will be worn by the patient. For this reason more or less reduction in the power of those chosen, when the ciliary muscle is under the influence of a cycloplegic and the pupils greatly dilated, must be made.

As stated above, there is a tendency for hyperopes to accommodate, and this tendency in young patients, or those between the ages of 10 and 40, covers up a part of their hyperopia. The amount of this error actually shown when the test is made under normal conditions is called "Manifest hyperopia," and that part covered up by a cramp of the ciliary muscle is called "Latent hyperopia." Possibly there are a few cases, and every refractionist has them, that ought to be refracted while under the influence of a reliable cycloplegic. For instance, children having a tendency to crossed vision (*strabismus*), probably should be refracted with the ciliary at rest. If they are not a long and tedious campaign may have to be undertaken. The eyes of such a patient should be examined often with a view to increasing the power of the lenses as the latent hyperopia becomes manifest, and this should be persistently done until the total error has been corrected.

If glasses that correct all of the hyperopia are worn continuously during waking hours, good results may be expected, especially if the vision is sufficiently good in both eyes to make binocular vision (vision with both eyes) better than monocular, or vision with a single eye.

When binocular vision is better than monocular there is a stimulant to fix both eyes upon the object viewed, but if it is not better no stimulant exists, and therefore one eye, usually the one having the least acuity, is left to the mercy of the extrinsic muscles of the eyes (the muscles that control the position of the eyes.)

When binocular vision exists the retinal image falls upon the macula or upon corresponding points of the retina of both eyes and the object is seen singly, but if both eyes are not directed correctly the images do not fall upon corresponding points of the retinas of the two, the result being that two

images of an object are seen, one being more or less blurred. This condition is known as "Diplopia" or double vision.

When single vision exists the visual axes of both eyes are directed toward the object viewed, and if the object is inside of infinity the two eyes are converged (turned in), the amount of convergence being governed by the distance that the object is from the eyes and the interpupillary distance.

Convergence is spoken of as so many meter angles. For instance, if both eyes fix upon an object one meter distant each eye converges one meter angle. If they fix upon an object $\frac{1}{2}$ meter distant, then they converge two meter angles each; if to a point $\frac{1}{4}$ of a meter distant, then four meter angles each, etc.

Meter angles of convergence and diopters of accommodation are used harmoniously, provided the eyes are emmetropic. For instance, an emmetrope viewing an object $\frac{1}{4}$ of a meter distant must put in force 4 diopters of accommodation, and also four meter angles of convergence; if the object is $\frac{1}{2}$ meter distant then 2 diopters of accommodation and 2 meter angles of convergence; if one meter distant then one meter angle of convergence and one diopter of accommodation, etc. Thus it will be seen that these powers, i. e., the accommodating and converging powers, are used harmoniously if the eyes are emmetropic, but if myopia exists convergence must be exercised in excess of accommodation, the amount of excess being governed by the extent of the myopia.

Just the opposite is true if hyperopia exists, for the hyperope must put in force some accommodation to see distant objects clearly, yet no convergence will be tolerated. The hyperope then uses accommodation in excess of convergence. When the hyperope is looking at distant objects, the visual axis of both eyes must be held perfectly parallel, yet he must put in force some accommodation if he sees clearly. For his hyperopia must be neutralized by accommodation or by + lenses.

Thus it will be seen that an error of refraction destroys that harmonious action between the accommodating and converging powers that exists when the eyes are emmetropic or normal.

It is possible to accommodate without converging; it is also possible to converge without accommodating, or to converge to one point and to accommodate for another; but when this is done there is not that harmonious action between these two powers that there ought to be, or that there is when emmetropia exists or when ametropic eyes have been made artificially emmetropic by means of lenses. Ametropia, then, causes a disturbance between the accommodating and converging powers, and this disturbance, known as muscle imbalance, causes more or less discomfort, often spoken of as "Asthenopia" or painful vision.

A muscular imbalance always causes eye strain, but such an imbalance may have existed for years, and the patient may have learned to overcome it, and thus formed a habit of converging without accommodating, as in myopia, or of accommodating without converging, as in hyperopia, and if they have formed these habits great care in prescribing correcting lenses should be exercised, especially if the refractive error be of considerable amount. For instance, suppose 3 diopters of hyperopia exists and the patient has never worn correcting lenses, if we correct the total amount of the error at once we have changed very materially the conditions under which the patient has always seen, and it may be difficult for them to accustom themselves to the changed conditions; but if we correct only half of the amount and in the near future correct one-half of the balance, and when possible the remainder, our patient will be likely to wear the glasses with comfort.

If myopia exists to a considerable extent it is never best to correct it in full at first, for the reason that the accommodation has lain dormant or has been used but little as compared with the convergence; but if minus lenses are worn, they will have to enforce accommodation to the full extent of the power of the lenses prescribed. Such lenses will call for a greater amount of accommodation for the amount of convergence put in force than has heretofore been used. The conditions, then, which the patient has been accustomed to will be more or less changed, according to the power of the lenses prescribed. Therefore the lenses must not be of a power that will cause the patient sufficient discomfort to discourage

them before they have worn them long enough to have become accustomed to them or to the changed conditions. Ultimately, however, the full correction may and *should be worn*, and worn with comfort, unless the error be very great.

Lenses, then, whether they be plus or minus, change the amount of accommodation called for and also the amount of convergence that must be enforced. If a hyperope of 2. D. sees distant objects clearly they must put in force 2. D. of accommodation, but must not converge at all, but if the hyperopia is corrected they will enforce neither accommodation nor convergence when looking at distant objects. Both of these powers will then be at rest, and only the normal or natural amount of accommodation and convergence will have to be put in force when looking at objects nearer the eyes than infinity. A myope of 3. D. must enforce three meter angles of convergence with each eye when viewing an object situated at their punctum remotum, which is only $\frac{1}{3}$ of a meter distant, yet they must not enforce the slightest amount of accommodation, for this would shorten the distance and therefore call for still more convergence.

If their myopia be corrected, however, they will be compelled to accommodate 3 diopters as well as to converge 3 meter angles when viewing objects located $\frac{1}{3}$ of a meter from the eyes, and when looking at distant objects they, like the emmetrope and the corrected hyperope, will neither converge nor accommodate,—both of these powers being at rest.

By the above it will be seen that a minus 2. D. spherical lens placed before a myopic eye brings into play two diopters of accommodation, and at the same time relieves the strain of converging 2 meter angles without accommodating 2 diopters, and that a — 3. D. lens will call for 3. D. of accommodation, but will relieve the strain of converging 3 meter angles without accommodating 3 diopters when looking at objects $\frac{1}{3}$ of a meter distant.

It will also be seen that a plus 1. D. sphere placed before an eye that is hyperopic 1. D. relieves the strain of accommodating 1. D. without converging 1 meter angle, and that a plus 3. D. lens relieves the strain of accommodating 3 diopters without enforcing any convergence.

If a patient be very hyperopic, say 3 or more diopters, they may not be able to accommodate sufficiently to overcome their hyperopia without converging. In other words they may not be able to accommodate sufficiently to see clearly without putting in force some convergence. In such cases both eyes will converge, but only one will fix upon the object, the other one being turned in excessively, so that its line of vision will cross that of the other eye, the result being diplopia or double vision. Such a condition is known as "Strabismus," often spoken of as "Cross-eye."

The eye may only stray temporarily at first, but in time it usually becomes permanently crossed. If it should the condition is known as "Convergent Strabismus," "Convergent Squint" or "Esotropia." The acuity of a squinting eye, for want of use, soon becomes impaired or amblyopic, and in time it may become quite sightless, therefore valueless as an aid in seeing. The brain seems to suppress the blurred image formed upon the retina of the squinting eye. This is done for the purpose of enhancing the value of the fixing one. If the child is too young to wear glasses the fixing eye should be covered for several hours each day; this will compel the use of the straying one and thus preserve its vision.

It will be seen by the above that if the Strabismus is caused by an error of refraction, which is usually the case, the error should be corrected at once or before the vision in the squinting eye has become much impaired. If it is the stimulant of binocular vision will aid in correcting the deviation.

If the vision has become impaired every effort should be made to the end that it be restored, especially if the patient be a child, which is usually the case. Children suffering from squint should be in the hands of a skilled operator; one who has had a wide experience in such cases, for the preservation of vision or its restoration, if it be impaired, is of the greatest importance. This is true whether we consider it from an economic or from a cosmic standpoint. A straying or squinting eye has always been and always must be considered a physical disfigurement. There seems to be but little excuse for such a condition in this the twentieth century.

The squint may not always be caused by ametropia, but may be caused by a weakness of one or more of the extrinsic muscles, or by a displaced one. In fact any disturbance in the power of the extrinsic muscles of the eye causes an ocular imbalance, known as "Heterophoria." Heterophoria, like Hyperopia, may be overcome by an increased innervation, but the extra nerve energy that is expended in directing the visual axis of two imbalanced eyes to a single point of fixation may cause muscular asthenopia or painful vision. For this reason the refractionist should be able to diagnose muscular anomalies as well as refractive errors.

Orthophoria.

When there is perfect muscular balance the condition is known as "Orthophoria." If Orthophoria exists each of the twelve extrinsic muscles of the eyes must have been perfectly developed and rightly attached to the globe, and each of them must be able to respond harmoniously to the innervations they receive, and there must be *no error of refraction*. But few people know of the joy of possessing a pair of orthophoric eyes.

The nomenclature of muscular anomalies suggested by Stevens of New York is now in general use. It is as follows:

Orthophoria—Perfect muscular balance.

Heterophoria—Imperfect muscular balance.

Orthotropia—Perfect binocular fixation.

Heterotropia—A decided deviation from parallelism.

Hyperphoria—A tendency of one eye to deviate upward.

Hypertropia—An actual deviation of an eye upward.

Esophoria—A tendency of the visual axes to deviate inward.

Esotropia—An actual deviation of of the visual axes inward.

Exophoria—A tendency of the visual axes to deviate outward.

Exotropia—An actual deviation of the visual axes outward.

Hyperesophoria—A tendency of the visual axes of the eye to deviate upward and inward.

Hyperesotropia—An actual deviation of the visual axes of one eye upward and inward.

Hyperexophoria—A tendency of the visual axes of one eye to deviate upward and outward.

Hyperextropia—An actual deviation of the visual axes of one eye upward and outward.

When there is only a tendency of an eye to deviate from its true position, the anomaly is known as “Insufficiency” or “Latent Deviation.” In such a condition one of the two opposing muscles is weak or works at a disadvantage. It therefore is unable to perform its natural function without undue strain.

Ametropia is the chief cause of muscular insufficiency. This being true, it is of the greatest importance that any existing error of refraction be corrected, and as a rule when this is successfully done the muscular insufficiency or imbalance will in a short time correct itself.

The extrinsic muscles of the eyes consist of two superior and two inferior recti, two internus and two externus, and two inferior and two superior oblique. The superior recti muscles elevate the eyes and the inferior recti depress them. The internus turns the eyes inward and the externus hold the visual axes of the two eyes parallel or slightly diverged. They also tend to prevent too great convergence. The oblique muscles aid the others in directing the visual axes of the two eyes toward the point of fixation.

Symptoms of Insufficiency.

The eyes become tired after prolonged use, especially if the source of illumination be artificial. After reading for a short time the letters seem to run together, and sometimes they appear to be double for a moment. One eye may appear to turn outward or inward, downward or upward.

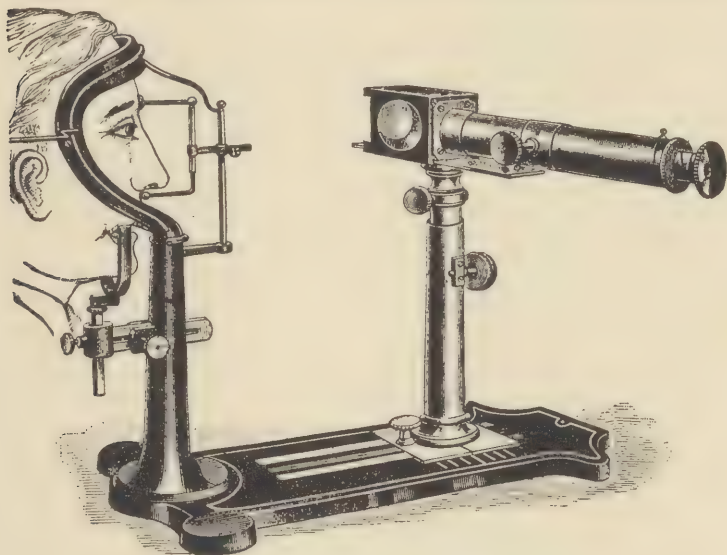
Fainting spells, dizziness and nausea are often complained of by patients suffering from muscular imbalances or a weakness of one or more of the extrinsic ocular muscles.

Simple Test for Insufficiency.

Convergence Test.—Let the patient fix upon the point of a pencil as it is slowly advanced in the median line toward the nose, the observer noting carefully the movement of the eyes. If one eye ceases to converge or deviates outward before

the other one does, an insufficiency of the internus is indicated. Both eyes should fix the pencil point as close as ten centimeters (4 inches).

Mobility Test.—An observer may note the excursions of the eyes by having the patient, while holding his head erect and practically motionless, follow the point of a pencil as the observer moves it up and down, and to the right and left. If the eyes move together, each one constantly fixing the point of the pencil as it is moved upward, say 35° and downward 55° , or to the right or left 45° from the central fixation point,



STEVENS TROPOMETER

the mobility of the eyes may be considered as being normal. The excursions of the eyes may be accurately measured with a Stevens Tropometer.

Cover Test.—When using this test the patient is instructed to look at a small light 6 meters distant. A light one centimeter in diameter and surrounded by a black field four or five feet in diameter is the ideal test object. While the patient is fixing the light with both eyes, the observer covers one of them for a few seconds, and then quickly removes the cover, noting at the time whether the eye just uncovered moves

inward, upward, or in any other direction. If it does insufficiency is indicated. For instance, if the eye moves inward when it is uncovered, the internus of one eye is weak or the externus is strong—at least an imbalance of the lateral muscle is shown. If the eye moves upward or downward, the vertical muscles are out of balance. Hyperphoria being indicated, and either one of the superior recti muscles is too weak or one of the inferior is too strong for its antagonist.

Prism Tests for Insufficiency.

Lateral Imbalance.—To test for lateral imbalance (Exophoria or Esophoria) the operator should produce vertical diplopia. This may be accomplished by placing a 10Δ prism before the right eye, base down. The patient should look at a small steady light six meters distant and in the center of a black field he will see two lights, one above the other. The upper one will be seen by the right eye, because the displacement of an image seen through a prism is always in the direction of its apex or thin edge. This being up the image will be up. If the upper light is directly over the lower one no insufficiency of the lateral muscles is apparent. If, however, the upper light is to the right of the lower one Esophoria is indicated. On the other hand, if the upper light is to the left of the lower one exophoria is present.

The amount of Esophoria or Exophoria is represented by a prism, which if placed before the left eye, base in or out, causes one light to be seen exactly over the other. According to the above displacement rule, the base of the prism before the left eye must be out if Esophoria is present, and in if Exophoria is present. When Esophoria is present the externi muscles are too weak for their antagonists, the interni, and therefore the eyes have a tendency to turn in. Just the opposite is true if Exophoria exists. The eyes then have a tendency to turn out because of weak internal muscles. By the above it will be seen that the base of the testing prisms is placed over the weak muscles.

When making muscle tests with prisms it is essential that the base of the prisms occupy correct positions. For instance, "base up" means that the base apex line or axes of the prism

must be exactly vertical with base at 90° . "Base in" means that the base must be toward the nose and that the base apex line must be exactly horizontal, or from 180 to 0 .

Lateral Imbalance for Near Point.—There may be no insufficiency shown when testing or using the eyes for distant vision, but there may be when using them for close work, reading, etc. The average distance at which such work is done is $\frac{1}{3}$ of a meter. Therefore 6 meter angles of convergence (three for each eye) must be constantly in force when reading or working at the average distance. If the antagonizing muscles (the internal and external) are not evenly balanced, there will be either esophoria or exophoria, provided the eyes are converged continuously for any great length of time. To determine the amount of lateral insufficiency at the reading distance have the patient look at a black line 3 or 4 inches long, having a dot at its center. This line and dot may be drawn upon a card which should be held $\frac{1}{3}$ of a meter from the eyes ($13\frac{1}{3}$ in.). The line should be in a vertical position and a prism of 10^Δ placed in the trial frame before the right eye, base down. Such a prism in such a position will produce vertical diplopia. If the patient sees a single line with two dots upon it, one dot being above the other, we may suppose that no insufficiency for the reading distance is present. If, however, the patient sees two lines, each having a dot at its center, there is an imbalance shown. If the upper dot and line are to the right of the lower one, there is an insufficiency of the externi (Esophoria for near), but should the upper dot and line be to the left of the lower one there is insufficiency of the interni. (Exophoria for near.) The amount of exophoria for near is represented by the power of the prism, base in, that places the two dots on a single line, one being above the other. If Esophoria is present the base of the measuring prism must be out.

Vertical Imbalance.—To test for Vertical Imbalance (Hyperphoria) a 10^Δ prism should be placed before the right eye, base in, axes exactly horizontal (180°). This prism so placed will produce lateral diplopia. The patient should look at a light six meters distant, the same as when testing for lateral insufficiency. His head should be erect and eyes on a level with

or slightly above the light. If the two lights seen lie in the same horizontal plane, i. e., are on a level, no vertical insufficiency is indicated, but should the light to the right be below or above the other one, hyperphoria is present. The prism base up before the left, or down before the right eye, that causes the two lights to be seen on a level, represents the amount of insufficiency.

Instruments for Muscle Testing.

Stevenson's Muscle Test.—There are various methods of testing for muscle imbalances or Phorias, both for the near and for the distant points, but a similarity exists between all of them. For instance, Dr. Mark D. Stevenson devised a Phorometer for measuring lateral insufficiency at the reading distance or at $\frac{1}{3}$ of a meter. This instrument contains two 5Δ prisms mounted in a chart holder, one prism being base up and the other base down. These prisms produce vertical diplopia practically the same as does a single 10Δ prism base down or up. In place of the line and dot chart described above, there is one having a line with an arrow pointing up at its center. Below this line is a scale graduated so as to show the amount of insufficiency or excess in prism *centrads*. Letters are placed above the line which may be read by the patient, enabling him to inform the operator to what letter on the displaced or upper line the arrow on the lower line points. If the arrow points to certain letters excessive convergence is shown, but if to others insufficient convergence is present. This instrument, therefore, enables the operator to determine practically the amount and also the variety of the insufficiency present when using the eyes for close work, reading, etc. If Presbyopia (old sight) is present the patient should be armed with his reading glasses which should enable him to see the figures below the line.

Stevens Phorometer.—The Stevens Phorometer is another illustration of practical instruments designed to measure insufficiencies or phorias. It consists of two prisms so mounted that either vertical or lateral diplopia may be produced, enabling the operator to test for both lateral and vertical imbalance. The character and the degree of the insufficiency may

be read from scales on the periphery of the cells carrying the prisms. A spirit level is mounted on this instrument. This prevents any inaccuracy in placing the base of the prisms used.

Savage Monocular Phorometer.—This instrument is based upon the principle that one eye should be entirely free from the other, and that this should be the fixing eye. The image in the other eye, which is the one to be tested, is thrown entirely beyond the field of possible binocular fusion, so that all the muscles of this eye may be free of nervous tension.

This instrument enables the operator to measure the power of each muscle of either eye separately. Scales on the instrument indicate the character and the degree of insufficiency.

Savage Cyclophorometer.—The cyclophorometer is an instrument designed to measure the power of the oblique muscles and to determine whether Orthophoria of the oblique muscles is present or absent. The instrument consists of a bar upon which is mounted a spirit level and two cells—one for each eye, these being adjustable for pupillary distance. Into each of these cells is placed a Maddox multiple rod; their axes being vertical. In front of one of these rods is placed a 5Δ prism, base up, and in front of the other may be placed a red or blue glass. The Maddox rods distort the light used as a test object into two horizontal streaks of light, one of which, owing to the prism, is seen above the other. If Orthophoria of the oblique muscles is present the streaks of light will be seen perfectly parallel. Should they not be parallel there is a want of Orthophoria. The streaks of light may be brought to parallelism by slightly rotating one of the rods. Each cell of the instrument is provided with a scale graduated in both the nasal and the temporal arcs; the graduations being in degrees of a circle with the starting point or "O" vertical.

The torsioning power of the inferior oblique muscles may be measured by rotating the axes of one rod toward the nose. To measure the superior oblique rotate a rod towards the temple. The fusing power of an oblique muscle is somewhere between 7° and 10° , the inferior having slightly greater fusing power than has the superior. With this instrument plus and

minus Cyclophoria and plus and minus Cycloduction may be measured. It also differentiates between symmetrical and non-symmetrical Cyclophoria.

Savage instruments, like practically all those used for muscle testing, are mounted on stands or brackets and provided with spirit levels.

THE FOGGING SYSTEM.

The so-called fogging system is now used quite extensively by refractionists who depend largely upon subjective methods for determining the kind and amount of ametropia present.

When this system is used every patient is made artificially myopic, + lenses having sufficient power to produce artificial myopia in all meridians of the eye are imposed before it. This procedure of course fogs the patient, hence the name fogging system.

It is claimed by many who use this system:

First, that the ciliary muscle is stimulated to relax rather than to contract as the examination proceeds.

Second, that the patient responds more readily to the questions asked them when — lenses are placed before their eyes than they do when + lenses are.

Third, that the principal meridians of an astigmatic eye are more easily located.

Fourth, that the meridian of least refraction rather than the meridian of greatest is corrected first.

Fifth, that more of the latent hyperopia is made manifest than when the old method is used.

Sixth, that more of the astigmatic error manifests itself.

Seventh, that when this system is properly used the eye is never given a chance to exercise its accommodation.

Eight, that if accommodation is put in force it is at the expense of vision.

The first claim that the ciliary muscle is stimulated to relax rather than to contract during the examination is practically conceded by all except those who insist that a cycloplegic should be used in all cases.

The second claim that the patient responds more readily to the questions asked them when — lenses are imposed before their eyes than they do when + are, is a debatable question. Of course the eye under examination is at the beginning practically myopic, and so long as it is each successive — spherical lens that is placed before the eye would improve vision (if its power is a little greater than the power of its predecessor and not great enough to over-correct the myopia, real or artificial), hence they would be expected to respond readily to the question "Is that better?" However, as the correction is approached the accommodation is likely to become active and cause the patient to hesitate when asked as to whether a certain lens makes the letters more or less distinct. If the interval between the — lens used to correct the artificial myopia is slight, say 0.25 or 0.12 (in other words if the myopia is corrected only a little at a time) the patient will recognize the improvement at once and therefore can respond quickly to the questions, but the examiner should never over-correct the myopia, real or artificial; therefore he should proceed carefully as the patient's vision approaches the normal.

The third claim that the principal meridians of an astigmatic eye are more easily located when this system is used than when + lenses only are used probably is true, for the reason that the punctum remotum of the meridian of least refraction is found while the remote point of the opposite meridian is still more or less fogged. The amount of the fog depending upon the amount of astigmatism present.

The fourth claim that the meridian of least refraction is corrected first is good, provided the interval between the — spheres placed before the eyes is less than the amount of uncorrected spherical error.

The fifth claim that more of the latent hyperopia is made manifest when the eye is fogged is conceded by practically all refractionists, provided the examination proceeds slowly.

The sixth claim that a greater amount of astigmatism will be found than by the old method of testing is possibly true provided there is no spasm of accommodation.

The seventh claim that the eye is not given a chance to accommodate is hardly true, but the eighth claim that if it

does put in force its accommodation it is at the expense of good vision, is clearly true.

Fogging with cylinders is beginning to receive attention. This scheme is to produce sufficient artificial myopic astigmatism to interfere to a considerable extent with the patient's vision. We will suppose that the patient reads 6/6 and possibly better without any lenses, and that weak spherical lenses, especially +, cause the letters to be more or less blurred and that the patient reports all the lines in the astigmatic dial equally distinct. So far no error of refraction is apparent. Suppose we place before the eye a + 1D cylinder with its axis horizontal this will cause some fog. We note the amount and then rotate the cylinder until its axis is vertical, and again note the amount of fog. If an improvement in vision has taken place we suspect that an astigmatic error exists, for if the eye were emmetropic, myopic or hyperopic simply the same amount of blurring ought to be noted in all meridians. Suppose that the 12 meter (40 foot) line of type were read when the axis was horizontal and that the letters in the 10 meter (30 foot) line could be correctly named when the axis was vertical, this would show that vision had been improved 10 per cent, indicating a low degree of astigmatism. If no improvement were noted the axis of the cylinder should be returned to its original position (horizontal) and then it should be slowly rotated, the patient being instructed to look steadily at the smallest letters that can be seen, and to report if at any point they become more distinct. If a point or meridian is found where the letters are seen more clearly, the axis of the cylinder should be placed at that point, and then the power of the + cylinder gradually reduced or neutralized by holding — cylinders over it, the axis of both lying in the same meridian.

It may be possible to discover a low degree of astigmatism by this method that would otherwise be overlooked. If so the method is quite important and should receive careful attention. If the principal meridians are oblique the axis of the + cylinder would have to be slowly rotated through a half circle, or from 0 to 180—, in order to locate one of the principal meridians.

The visual acuity of a patient may be below the normal or the astigmatic error so slight that the patient is unable to differentiate between the lines of the astigmatic dial — those that are sharply focused or distinct, and those that are more or less blurred. Now, if the blurred lines are still further blurred by the cylinder, the patient will possibly be able to differentiate between them and to report this fact to the examiner. If they are able to do this the examiner has a starting point from which he may be able to reach a correct solution.

TRIAL CASE ACCESSORIES.

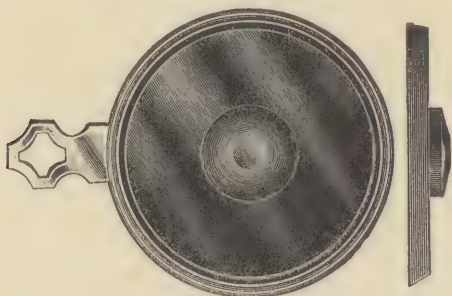
There are several Trial Case Accessories designed to be used as aids when testing for muscular imbalances. Among them are the Maddox Rod, the Maddox Double Prism, the Truncated Cone Prism and the Thorington Truncated Prism.

The Maddox Rod.—The Maddox Rod consists of a small glass rod or cylinder, or a multiplicity of them mounted in the center of a metal rim similar to the trial lens rims, so that it may be placed in a cell of the trial frame. This rod when placed before an eye distorts the light used as a test object into a streak of broken light, the streak being at right angles to the axis of the rod. This streak of light seen by the covered eye is so unlike the light seen by the uncovered one that the patient makes no special effort to fuse the two. Therefore the muscles of the two eyes are at liberty to place each of them into positions of rest. The stronger muscles will then dominate the weaker ones and rotate the two eyes into positions where there will be no strain. The Maddox Rod then enables the operator to measure vertical and lateral imbalances in practically the same manner as they are measured by producing vertical or lateral diplopia by means of prisms.

The Maddox Rod also enables the operator to measure hyperexophoria and hyperesophoria. When measuring these muscular anomalies two prisms are required, one base in or out, and the other base down before one eye or up before the other. The correction of these errors may be made with a single prism, provided its base lies in the proper meridian. (See Cogan Prism Chart, page 74.)

Maddox Double Prism.—What is known as a Maddox Double Prism consists of two prisms of equal power mounted in a trial lens rim with their bases together. Such a prism, if correctly placed before an eye, causes it to see two images of a single light, one being displaced in one direction and the other in the opposite direction.

The patient when fixing with both eyes will see three lights. If these three are in a straight line and the central one seen by the uncovered eye is continuously midway between the other two when the prism is rotated through a half circle, orthophoria may be considered as being present. Should the lights not be in line, or the central one not be midway between the other two when the prisms occupy different positions, heterophoria is indicated. Lateral insufficiency (esophoria or exophoria) is indicated if, when the bases of the prisms are up and down, the central light is to the right or left of the other two. Vertical insufficiency (right or left Hyperphoria) is indicated if, when the basis of the prisms are out and in, the three lights are not in line, i. e., are not on a level. The prism which causes the central light to be seen in line with the other two represents the insufficiency.



THE TRUNCATED CONE PRISM

The Truncated Cone Prism (Patented).—The truncated cone prism consists of a cone prism mounted on a cobalt blue lens, the density of which is such as to exclude from the eye over which it is placed all but red and blue light. The top of this cone is cut off (truncated), thus forming a plano lens in

the center of a cone prism which is mounted in a trial lens rim. Such a prism causes the eye over which it is placed to see the test light in the center of a ring or circle of light, both the circle and the light at its center being blue. If orthophoria is present the test light will be seen by the uncovered eye as a natural white light exactly superimposed over the blue light seen by the covered eye. These two lights, one blue and the other white, will not only be seen superimposed, or over each other, but also in the center of a circle or ring of blue light. Should the two lights not be superimposed a muscular imbalance is present.

The power of the truncated cone prism being six degrees enables the operator to estimate very closely the power of a prism which will measure the insufficiency or muscular imbalance. For instance, if the truncated prism be placed before the right eye and the white or natural light seen by the left eye is to the right of and midway between the blue light and the circle of light, three degrees of exophoria is present. If the white light is seen on the circle of light, six degrees is the amount of the error.

If the white light is above or below the blue light hyperphoria is present. If it be seen to the left of the blue light esophoria is present. If the white light is to the left or the right of the blue and also above or below it, hyperesophoria or hyperexophoria is present. The position of the white light in relation to the blue light indicates the character of the imbalance, and the position of the white light in relation to the circle of light indicates the amount of the insufficiency.

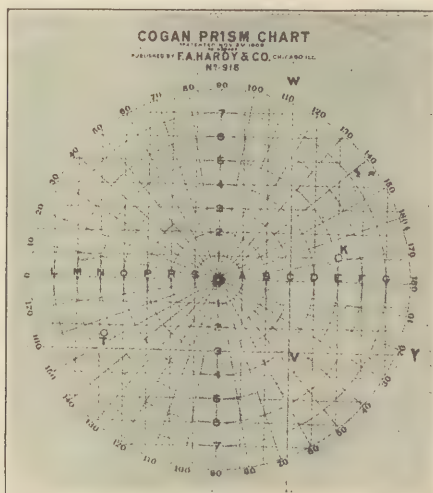
The cone prism may be placed over either eye, so also may the measuring prism, but as a rule it is the best to place the cone prism over the right eye and the measuring prism over the left with its apex in the direction that the white light is to be moved, in order that it may be superimposed over the blue light. The truncated cone prism makes the diagnosing and measuring of muscular imbalances exceedingly simple.

The two lights are so dissimilar that the patient makes practically no effort to fuse them.

The truncated cone prism being mounted on cobalt blue glass of the proper density to exclude all but red and blue

light, makes it a most excellent chromatic test for diagnosing errors of refraction, as well as a test for diagnosing and measuring muscular imbalances.

The Thorrrington Truncated Prism.—This prism is made of a single piece of colored glass, either ruby red or cobalt blue. Between the two prisms which are bases together is a plain strip 3 millimeters wide. When looking at the test light through this prism, the patient sees three colored lights connected by a streak of light. The color of these lights and



the streak connecting them are decidedly different from the white light seen by the uncovered eye. If Orthophoria for distance is present the central colored light and the white light seen by the uncovered eye will be superimposed. If Heterophoria exists the white light will be to the right or left, or above or below the central colored light. The prism which causes the central colored and the white light to be superimposed represents the insufficiency present.

The Cogan Prism Chart.—The Cogan Prism Chart furnishes one of the simplest means of testing for muscular errors that has been devised. No instrument, of any character,

not even a prism, is required when making a test with this chart. The amount of prismatic power required and the exact position to place the base of the measuring prism (no matter what the deviation may be) is found at once and may be read directly from the Chart.

Colored Trial Lenses.—The dark red and blue lenses usually found in Trial Cases are designed to be used as aids when testing ocular muscles by means of prisms. In fact a colored lens should practically always be used over one eye when making tests for muscular insufficiencies. Such a glass, either red or blue, causes the light seen by the eye over which it is placed to appear as a red or blue light. This enables the patient to differentiate between the lights seen by each individual eye. It also causes the two lights to be dissimilar or unlike. Therefore the tendency of the eyes to fuse the two is materially lessened.

Tropias.—There is a decided difference between what is known as “Phorias” and what is known as “Tropias.” The former being simply a tendency to deviate from the correct position, while the latter is an actual deviation, or a deviation which causes absolute diplopia. Such a deviation as convergent squint is termed “Esotropia.” Should the squint be divergent it is known as “Exotropia.” If one eye actually turns up sufficiently to produce diplopia, the deviation is known as “Right Hypertropia” or “Left Hypertropia.”

Stevens Tropometer.—Tropias are best measured with a Stevens Tropometer. Such an instrument is very useful provided a tenotomy of the muscles is to be resorted to.

ACCOMMODATION

The power of the eye to vary its refraction is known as accommodation for the reason that an eye that has this power accommodates itself to waves of light that have traveled different distances after leaving a radiant point. These waves have more or less divergence according to the distance which they have traveled. If the distance be great very little divergence exists, therefore very little accommodation is required to focus them upon the retina of an emmetropic or normal eye. But if the light has traveled a meter the divergence amounts to one diopter and this amount of increased refraction is called for provided these light waves are sharply focused upon the retina of an emmetropic eye.

If the object viewed is one-fourth of a meter distant then four diopters of divergence exists, therefore four diopters of increased refraction must be put in force if a sharp image of the object is formed upon the retina. And according to the law of divergence ten diopters of accommodation must be enforced if light waves from an object situated $1/10$ of a meter distant are sharply focused upon the retina of a normal eye. The power of accommodation is then a most valuable one for it enables those who possess it to see objects close at hand as well as distant objects.

It is not known positively how this increased refraction is brought about but it is known that it exists and also that it is steadily lost as age advances, the loss being a regular one, so regular in fact that one's age may be closely calculated if the power of accommodation is known. It is supposed that the loss of this power is caused by a hardening of the crystalline lens; it is also supposed that this hardening is caused by a lack of nutrition or by lime deposits such as takes place in the bones or frame work of the body, but exactly why the crystalline lens should become so hardened that it is unable to perform its natural functions properly is yet a mystery.

That this hardening process begins early in life and continues steadily as the years go by is well known. It is also well known that the loss of this power causes the near point of distinct vision to recede and that this recession is a measure of this power remaining at any time. A normal eye, or one known as emmetropic, is one whose refraction (when the accommodation is at rest) is adjusted for rays coming from points at infinity. When accommodation is put in force the eye is adjusted for points inside of infinity and the nearest point that a normal eye can accommodate for represents the measure of its accommodating power.

For instance if a normal eye can see distinctly an object located 7.1 centimeters from it, it can put in force 14 diopters of accommodation and this amount is the average possessed at the age of 10. This near point of distinct vision is known as the punctum proximum (abbreviated p. p.), while the far point is called the punctum remotum (abbreviated p. r.) and the interval between these two points (the far and the near) is known as the range of accommodation. At the age of 10 the range of a normal eye is from about 7 centimeters to infinity ($2\frac{3}{4}$ inches to infinity) as stated above; this range represents 14 diopters.

As age advances the range decreases so that at the age of 70 the p. p. has receded until it coincides with the p. r., in other words the near and the far points are the same. When the proximum point of a normal eye has receded to 10 centimeters the accommodation has decreased to 10 diopters which is the average or normal amount for the age of 20; after this age the decrease amounts to almost exactly $\frac{1}{4}$ of a diopter each year. The fact that accommodation is lost at the rate of $\frac{1}{4}$ diopter each year until the ages of 60 or 65, when all is lost as well as the proximum points and the normal amount of accommodative power at different ages from 10 to 65, should be as familiar to the up-to-date refractionist as is the power of the lenses in his trial case. All eyes of course are

not normal, some having excessive refraction and others are deficient in this power.

The former are said to be myopic and the latter hyperopic. The remote point (p. r.) of a myopic eye on account of its excessive refraction is always at a definite distance inside of infinity, the distance being governed entirely by the amount of myopia present. The remote point (p. r.) of a hyperopic eye may be said to be beyond infinity and the distance that it is beyond infinity may be expressed in diopters the same as accommodation is expressed in diopters. For instance, if the eye is deficient in refraction to the extent of 2 diopters, in other words, if it is hyperopic 2 diopters, its p. r. may be said to be 2 diopters beyond infinity for this amount of refracting power must be added to its inherent power if rays from infinity are to be focused upon its retina. This amount of refraction must be added either by accommodative effort or by placing before the eye a plus 2 diopter lens. By the above it will be seen that a part of the accommodation of an uncorrected hyperopic eye must be used in order to see distant objects clearly. The p. p. then of a hyperopic eye is always farther from the eye than is the p. p. of an emmetropic eye. Just the opposite is true of a myopic one, its p. p. is just as much nearer to the eye as it has myopia. If the near points for normal eyes at different ages is known it is an easy matter to estimate the probable extent of myopia or hyperopia present and if this is possible why is it not also possible to estimate the amount of latent hyperopia and also to differentiate between real myopia and that caused by a spasm of accommodation. If the accommodating power of an eye at a given age is of a certain amount or nearly a certain amount and according to the best authorities it is then the near point of distinct vision if compared with the age of the patient gives us an exceedingly strong hint as to where the far point is or ought to be. Thus if the near point (p. p.) at the age of 20 is 8 instead of 10 centimeters we must conclude that myopia to the extent of $4\frac{1}{2}$ diopters is probably present or at least

that amount is indicated. On the other hand if the near point is $12\frac{1}{2}$ instead of 10 centimeters distant at the above age it is perfectly natural to suspect that 2 diopters of hyperopia is present and that this amount of the patient's accommodation was used to overcome it.

This leaves only 8 diopters to be shown by the near point. If no hyperopia had been present the proximum point would have been 10 instead of $12\frac{1}{2}$ centimeters. In order to locate the near point accurately and thereby make it of value in estimating errors of refraction and to determine the amount of accommodation present at any particular time the retinal image should be of a correct size, in other words, if letters or characters are used as a test object they should be of a size that will produce a retinal image of the prescribed size, i. e., they should subtend an angle of 5 minutes at certain distances from the eye. The retinal image will then be the same size that is produced by a 6 meter letter when viewed from a distance of 6 meters. The type to be had that is designed to do this is very inaccurate, especially when used at 20 centimeters or less, for it is much too large; it therefore may be read at a shorter distance than it could be if it were of the correct size. It is a fact that it is not practical or possible to print letters small enough for the different distances at which the tests must be made and for this reason the test for the near point as made ordinarily is very inaccurate and therefore more or less unreliable. Fortunately there is an instrument (the Punctumeter) for doing this work in a dependable manner for these instruments maintain a retinal image correct in size, no matter where the near point of distinct vision is located; with one of these a near point of 7 centimeters may be as accurately located as one of 70 centimeters. Instruments for doing this work are based upon the principal of the conjugate focus of lenses. The following scale of near points for different ages together with their normal amount of accommodation for the age given should be perfectly familiar to all who make the correction of refractive errors a specialty:

Age in years	Accom- modation in diopters	Punctum proximum in centimeters
10.....	14.	7.1
12.....	13.	7.7
14.....	12.	8.3
16.....	11.	9.1
18.....	10.50	9.5
20.....	10.	10.
22.....	9.50	10.5
24.....	9.00	11.1
26.....	8.50	11.7
28.....	8.00	12.5
30.....	7.50	13.3
32.....	7.00	14.2
34.....	6.50	15.3
36.....	6.00	16.6
38.....	5.50	18.1
40.....	5.00	20.
42.....	4.50	22.2
44.....	4.00	25.
46.....	3.50	28.2
48.....	3.00	33.3
50.....	2.50	40.
52.....	2.00	50.
54.....	1.50	66.6
56.....	1.00	100.
60.....	.50	200.
70.....	.00	infinity

If the accommodation of each eye be measured accurately it may be found that one possesses more than its fellow, if so, great care must be exercised in prescribing glasses for close work, especially if the difference between the fellow eyes be marked. One of them may have but little reserve accommodation while the other may possess more than is necessary for comfortable work at the near point. It is generally conceded that only about 60 per cent of the total accommodation possessed at any particular time can be used for sustained vision.

This being true at the age of 40 when the accommodation amounts to 5. D., patients that wish to hold their work at a distance of $\frac{1}{3}$ of a meter would put in force 3. D., which is 60 per cent of the 5. D.; they would then have a reserve force of 2. D., which is sufficient, but when the p. p. has receded to 22 centimeters, as it has at the age of 42, presbyopia is said to have appeared. The eye then has but 4.50 D. of accommodation, therefore if they work at $\frac{1}{3}$ of a meter they will have to use 66.66 per cent of their accommodation or hold their work at a greater distance, which they usually do, or they may seek a better light, either of which will enable them to put off the use of reading glasses a while longer, but finally they must resort to their use. If the accommodating power present at any time is known it is quite a simple matter to prescribe lenses that will enable them to work at their accustomed distance without discomfort. If myopia is present their p. p. may never recede to or beyond 22 centimeters. If so, they will always be able to see near at hand without the aid of plus lenses. But if hyperopia is present the p. p. will recede to or beyond 22 centimeters before the age of 42 and they will then have to resort to the aid of plus lenses when working close at hand. If an error of refraction exists and it be corrected with suitable lenses, the eye is supposed to be made artificially emmetropic or normal. Such eyes rarely need the aid of extra lenses when reading or working at the usual distance before the age of 42. It is safe to allow presbyopes to use 60 per cent of the accommodation present and to prescribe enough, which if added to their useful accommodation will enable them to see at $\frac{1}{3}$ of a meter. Thus suppose there exists 3.25 of accommodation, 60 per cent of this amounts to 1.95, therefore +1.05 or practically +1. D. will be the lens to prescribe for their presbyopia.

Every one prescribing glasses should know all about the accommodation of every patient before they write a formula for lenses. If they do serious errors may be avoided.

ACCOMMODATION AND PRESBYOPIA.

It is said that the refracting media of a normal eye acts like a strong convex spherical lens; that it converges the light waves that enter it, so that they are brought to an exact focus upon its retina, and that there is then a picture of the object, from which the light waves came, formed upon the retina, and that this picture is transmitted by the nerve fibers, which compose the retina, to the brain, and that if the brain be normal it transmits this picture to the mind or to the soul, and we see.

Waves or rays of light in nature are always divergent, and the amount of this divergence is governed entirely by the distance they have traveled after leaving their source, an illuminated point. At $1/10$ of a meter from the luminous point the divergence amounts to exactly 10. diopters, at $1/4$ of a meter it amounts to 4. diopters, at one meter it amounts to 1. diopter, at six meters the divergence amounts to $1/6$ of a diopter; but they are for all ordinary optical purposes considered as being parallel.

The above being true, the refracting media of an eye cannot always act exactly like a strong convex spherical lens, for if it did only rays of light that had traversed a certain distance would be sharply focused upon its retina. Therefore, if rays diverging from points on objects situated at different distances from the eye must be brought to an exact focus on its retina, the eye must adjust its refraction to suit these different distances. For instance, an emmetropic eye, or one adjusted for parallel rays, wishing to see distinctly an object located $1/4$ of a meter distant, must increase its refraction to the extent of 4. diopters, for it requires that amount of refracting power to make rays diverging from points $1/4$ of a meter distant parallel, or suitable for an emmetropic eye in a state of rest. If the object be only $1/10$ of a meter distant 10. diopters is required to parallel the rays.

This power to increase the refraction of the eye is known as "accommodation," for the reason that an eye that possesses it accommodates itself to rays differing in amounts of diverg-

ence. The amount of this power possessed by normal eyes varies according to the age and physical condition of the patient. At the age of ten it amounts to 14. diopters, at fifteen it has decreased to 12. diopters, and at twenty only 10. diopters remain. An emmetropic eye possessing this amount (10 D.) will be able to see distinctly for a short time only objects as close to the eye as $1/10$ of a meter (10 c. m.).

Punctum Proximum.

The nearest possible point to the eye that can be accommodated for is known as the "punctum proximum" (abbreviated p. p.). At the age of thirty the accommodating power has decreased to 7.50 diopters; the near point, or p. p., is then $13\frac{1}{2}$ centimeters distant. At the age of forty only 5. diopters of this power can be put in force; the p. p. has therefore receded to $\frac{1}{5}$ of a meter (20 c. m.). At the age of fifty there remains but 2.50 diopters; the p. p. is then 40 c. m. distant. At sixty very little accommodation is present, at least very little that can be used for sustained vision. We say "sustained vision" for the reason that all of the accommodating power that an eye possesses cannot be used for a considerable length of time without causing fatigue or painful vision, often spoken of as "accommodative asthenopia." The amount of this power that can be used for sustained vision without causing fatigue, varies only slightly; probably not more than 60 per cent of the total present at any particular time can be used continuously without causing asthenopia.

The average person reads at $\frac{1}{3}$ of a meter ($33\frac{1}{3}$ c. m.). 3. diopters is then the average amount of accommodation that an emmetropic eye puts in force when doing work close at hand. This amount is 60 per cent of the total present at the age of forty. Therefore at this age an emmetrope can accommodate for a distance of $\frac{1}{3}$ of a meter and yet have 2. diopters in reserve, but an uncorrected hyperope of 1. diopter wishing to see at $\frac{1}{3}$ of a meter would have to use 1. diopter of his accommodation to overcome his hyperopia, and this amount would have to come from his reserve power. Therefore, such an eye would require more than a total of 5. diopters if it sees comfortably at $\frac{1}{3}$ of a meter. On the other

hand, an uncorrected myope of 1. D. possessing 5. D. of accommodation would be able to see comfortably at $\frac{1}{3}$ of a meter when using only 2. D. of his 5. diopters of accommodation. The myope of 1. D. then, at the age of forty, uses only 40 per cent of this power which is present.

HARMONIOUS ACTION OF THE ACCOMMODATING AND CONVERGING POWERS.

It is generally understood that the powers of accommodation and convergence only act harmoniously when the eyes are emmetropic and both of them have the same visual acuity. But something more than this is necessary if we are to have comfortable binocular vision. In other words, if the eyes are emmetropic and have the same visual acuity and all of the extrinsic muscles of the eyes perform their functions so that comfortable and harmonious binocular vision results, then we may say that there is harmonious action of the accommodating and converging powers. Such action usually results as above or in good and comfortable vision. Accommodation is the power of the eye to adjust itself to see objects situated within its far point or *punctum remotum*. Convergence is the power to turn the visual axes of the eyes in, so that they will both be directed toward the object looked at. Accommodation is necessary because the rays of light from the object viewed must be sharply focused upon the retina and convergence is necessary because the images or pictures of the object viewed must fall upon corresponding parts of the two retinas; if they do not so fall, double vision results. Our accommodation then must be right, or vision will be imperfect. Vision will also be imperfect if the pictures formed on the retinas do not fall upon corresponding points of the two retinas. If the latter is but a trifle off imperfect vision results; if considerable off, double vision must result. Convergence is spoken of as so many meter angles. For instance, if both eyes fix upon an object one meter distant, each eye is said to have converged one meter angle. If they fix upon an object $\frac{1}{2}$ meter distant then they have converged two meter angles each; or if they converge to a point $\frac{1}{4}$ meter distant they have converged 4

meter angles each, etc. Accommodation is spoken of as so many diopters. The amount required for any particular point being but sufficient to parallel the rays of light diverging from that point, provided of course that the eyes receiving the light are emmetropic. An emmetrope then viewing an object $\frac{1}{4}$ meter distant must put in force 4 diopters of accommodation and also 4 meter angles of convergence. If the object be $\frac{1}{2}$ meter distant then 2 diopters of accommodation and 2 meter angles of convergence must be put in force. If the object be 1 meter distant then 1 diopter of accommodation and 1 meter angle of convergence for each eye must be enforced, etc. Thus it will be seen that these powers, i. e., the powers of accommodation and convergence, are used harmoniously if the eyes are emmetropic. But if myopia exists convergence must be exercised in excess of accommodation, the amount of excess being governed by the extent of the myopia.

Just the opposite is true if hyperopia exists, for the hyperope must put in force some accommodation to see distant objects clearly, yet no convergence will be tolerated. The hyperope then uses accommodation in excess of convergence. When the hyperope is looking at distant objects, the visual axis of both eyes must be held perfectly parallel, yet he must put in force some accommodation if he sees clearly. For his hyperopia must be neutralized by accommodation.

Thus it will be seen that an error of refraction destroys that harmonious action between the accommodating and converging powers that exists when the eyes are emmetropic, or normal.

It is possible to accommodate without converging, it is also possible to converge without accommodating, or to converge to one point and to accommodate for another, but when this is done there is not that harmonious action between these two powers that there ought to be, or that there is when emmetropia exists or when ametropic eyes have been made artificially emmetropic by means of lenses. Ametropia then causes a disturbance between the accommodating and converging powers, and this disturbance, known as "Imbalance," causes more or less discomfort, often spoken of as "Asthenopia," or painful vision.

A muscular imbalance always causes eye strain, but such an imbalance may have existed for years, and the patient may have learned to overcome it, and thus formed a habit of converging without accommodating, as in myopia, or of accommodating without converging, as in hyperopia, and if they have formed these habits great care in prescribing correcting lenses should be exercised, especially if the refractive error be of considerable amount. For instance, suppose 2 diopters of hyperopia exists and the patient has never worn correcting lenses, if we correct the total amount of the error at once we have changed very materially the conditions under which the patient has always seen, and it may be difficult for them to accustom themselves to the changed conditions, but if we correct only half of the amount and in the near future correct one-half of the balance, and when possible the remainder, our patient will be likely to wear the glasses with comfort.

If myopia exists to a considerable extent it is never best to correct it in full at first, for the reason that the accommodation has lain dormant or has been used but little as compared with the convergence, but if minus lenses are worn, they will have to enforce accommodation to the full extent of the power of the lenses prescribed. Such lenses will call for a greater amount of accommodation for the amount of convergence put in force than has heretofore been used. The conditions, then, which the patient has been accustomed to will be more or less changed, according to the power of the lenses prescribed. Therefore the lenses must not be of a power that will cause the patient sufficient discomfort to discourage them before they have worn them long enough to have become accustomed to them or to the changed conditions. Ultimately, however, the full correction may and should be worn with comfort, unless the error be very great.

Lenses, then, whether they be plus or minus, change the amount of accommodation called for and also the amount of convergence that must be enforced. If a hyperope of 2. D. sees distant objects clearly they must put in force 2. D. of accommodation, but must not converge at all, but if the hyperopia is corrected they will enforce neither accommodation nor convergence when looking at distant objects. Both of these

powers will then be at rest, and only the normal or natural amount of accommodation and convergence will have to be put in force when looking at objects nearer the eyes than infinity. A myope of 3. D. must enforce 3 meter angles of convergence with each eye when viewing an object situated at their punctum remotum, which is only $\frac{1}{3}$ of a meter distant, yet they must not enforce the slightest amount of accommodation, for this shortens the distance and therefore calls for more convergence.

If their myopia be corrected, however, they will be compelled to accommodate 3 diopters as well as to converge 3 meter angles when viewing objects located $\frac{1}{3}$ of a meter from the eyes, and when looking at distant objects they, like the emmetrope and corrected hyperope, will neither converge or accommodate,—both of these powers being at rest.

By the above it will be seen that a minus 2. D. spherical lens placed before a myopic eye brings into play 2 diopters of accommodation, and at the same time relieves the strain of converging 2 meter angles without accommodating 2 diopters, and that a — 4. D. lense will call for 4. D. of accommodation, but will relieve the strain of converging 4 meter angles without accommodating 4 diopters.

It will also be seen that a plus 1. D. sphere placed before an eye that is hyperopic 1. D. relieves the strain of accommodating 1. D. without converging 1 meter angle, and that a plus 3. D. lens relieves the strain of accommodating 3. diopters without enforcing any convergence.

If a patient be very hyperopic, say 3 or more diopters, they may not be able to accommodate sufficiently to overcome their hyperopia without converging. In other words they may not be able to accommodate sufficiently to see clearly without putting in force some convergence. In such cases both eyes will converge, but only one will fix upon the object; the other one being turned in excessively, so that its line of vision will cross that of the other eye, the result being *dyplopia* or double vision.

Accommodation seems to stimulate convergence but convergence does not always stimulate accommodation. This being true, how are we to know whether these powers are in harmony or not. If they are out of harmony headaches and other

distressing troubles will appear. Many optometrists will say that they are not in harmony if not used in equal amounts, but this is not necessarily true. Emmetropes are the only ones whose accommodation and convergence are in harmony when used in equal amounts. Hyperopes, like emmetropes, do use their accommodation and convergence in equal amounts, and that seems to be the trouble. To illustrate, a hyperope of 1. D. when he looks at a distant object must put in force 1. D. of accommodation; this will stimulate 1 meter angle of convergence, but he does not need any. What does he do but try to lessen the convergence, and we all know how hard that is to do. Anyone with little practice can look cross-eyed, that is, they can turn both eyes in, but they cannot turn both eyes out at the same time.

The hyperope who uses 1. D. of accommodation must stimulate 1 meter angle of convergence, and this he does not need. The hyperope then cannot use his accommodation and convergence in harmony as does the emmetrope. This being true, we must say that these powers are used harmoniously only when the accommodation stimulates the proper amount of convergence. The emmetropes accommodation does stimulate the proper amount, but the hyperopes do not, although the accommodation and convergence may be of equal amount in both cases. The uncorrected hyperope's accommodation and convergence are then always out of harmony and headaches or eye strain are the result. Now the question is how to balance these powers so that the headaches will disappear. If we correct all of the hyperopia they will still have headaches, but if we correct enough to harmonize the accommodation and convergence the headaches will cease. The uncorrected hyperopia will cause some exophoria as a rule but this in time usually corrects itself. When it does it is time to increase the power of the lenses or to correct the error in full. If a partial correction produces exophoria the patient will use sufficient accommodation to stimulate enough convergence to overcome the exophoria and to converge the eyes properly. This puts the accommodation and the convergence into harmony. Prisms properly placed before a patient's eyes will produce exophoria, and if they produce just as many degrees

of exophoria as he has diopters of hyperopia the accommodation used to correct his hyperopia will stimulate just enough convergence, thus putting these powers exactly into harmony. Simple prisms then may cause headaches to disappear. Hyperopia with exophoria is unusual, the tendency is for hyperopes to have esophoria, for excessive convergence tends to strengthen the internal rectus muscles. As stated above, a myope needs to use his convergence in excess of his accommodation. He then soon learns to converge without accommodating and may converge as many meter angles as he has diopters of myopia before he puts in force any accommodation. He thus forms a habit of converging without accommodating and this habit once formed is hard to overcome. A myope of 1. D. does not need any accommodation when viewing an object 1 meter distant, but he does need 2 meter angles of convergence (one for each eye). Now he can and does learn to converge that amount without accommodating and after doing this thousands of times it becomes a fixed habit with him, and this habit is hard to overcome. Suppose a myope of 2. D. has never worn glasses and we place his full correction before his eyes and ask him to look at an object 1 meter distant; he then, from force of habit, converges 1 meter angle and must put in force 2 diopters of accommodation, and this stimulates 2 meter angles of convergence. He then is converging 3 meter angles instead of 1, or the amount required. His accommodation and convergence are then certainly out of harmony.

There is then a good reason why myopia should not be corrected in full at the first attempt. There is also just as good a reason why hyperopes should not be corrected in full at first, but both of these errors may and should eventually be corrected, practically in full. When making the test only one eye is being used, therefore convergence does not enter into the problem, but when both eyes are being used, as when the final test is made or glasses worn, convergence does enter into the problem, it therefore should be carefully considered when balancing up the powers of accommodation and convergence so as to produce harmonious action between them.

PRESBYOPIA.

Presbyopia (often called old sight) is considered by many refractionists to be an easy ocular proposition, but there are so many conditions to be considered when relieving presbyopic conditions, that the writer cannot consider it an easy problem to decide exactly what + spherical lenses, added to the distance correction, will give the patient what they desire *good* and *comfortable binocular vision* at their preferred distance.

These conditions are pupillary distance, occupation, illumination, working distance, patient's age, accommodation present, length of arms, their converging powers, their mental and physical stability and also their visual acuity. All these conditions must be carefully considered if satisfactory results are to be secured.

It would seem that if no uncorrected error of refraction existed that all that was needed was to render parallel the rays diverging from the near points before they entered the patient's eyes, so that if their vision was fair for distant points, it would also be fair for near points, but when the conditions named above, and possibly others, are considered, we must agree that the successful correction of presbyopia is not always an easy ocular proposition, for every one of the above conditions are important, and when we consider that two or three, or possibly more of the conditions may need consideration in any particular case, we must agree that the correcting of presbyopia may be quite a complicated affair.

For instance, let us suppose that a patient has a very wide pupillary distance and also has low visual acuity. This low acuity compels them to hold their work close for the purpose of enlarging the retinal images, and the holding of the work close, together with their wide p. d., brings into play great convergence which may not be easily accomplished; if it is not, uncomfortable vision at the near point is the result. A case such as cited must show the possibilities that may be encountered when correcting presbyopia.

The first of the above conditions (the p. d.) is very important. This should be measured while the patient is con-

verging to the near point. The second (the occupation) is also important for they may wish to see clearly at a certain distance and this distance must be known. The illumination: The patient may have an occupation which compels him to see at a long or a short distance; therefore he must be corrected for that particular distance. The age of the patient should be known for their age furnishes a clew to the sixth condition (the accommodation present). Generally speaking, 60 per cent of this power present at any time may be used for sustained vision; this means that the other 40 per cent must be supplied in the shape of $+$ spherical lenses. The length of the arms should be noticed, for a patient with long arms naturally holds his paper farther from his eyes than does one with short arms. He then uses less accommodation and also less convergence. The mental stability of a patient must also be considered carefully; also his visual acuity. If this be normal or better, his range of vision will be greater than it would be if his acuity was below the standard.

From the case cited above it will be seen that it is not always an easy ocular proposition to prescribe for a presbyopic patient, but if every possible condition is carefully considered and the correction is made accordingly, the glasses ought to be satisfactory. Of course it is impossible to enable a nearly blind patient to see both well and comfortably, but if records are carefully made it will be possible to tell at any time the reason for poor or uncomfortable vision.

If the patient has been wearing glasses which have proven satisfactory but now require to be supplemented by those having greater power, it is a simple matter to prescribe the proper lenses. Such cases usually require $+ 0.50$ to 1.00 S. added to their old lenses to bring the proximum point forward. Accommodation is lost at the rate of 0.25 a year so that if the glasses had been worn four years, the accommodation would be 1.00 D. less than it was when the glasses were fitted. A large percentage of this loss must be added to their lenses. As a rule $+ 0.75$ D. for four years will be sufficient.

PRESBYOPIA.

Whenever the time arrives that a patient cannot accommodate for a distance of $\frac{1}{3}$ of a meter without causing asthenopia, presbyopia (old sight) is said to have set in. The symptoms of presbyopia are a tendency to seek a better light and to hold the paper further from the eye than usual, thus calling for the less accommodation. The eyes tire quickly, causing the patient to close them frequently for the purpose of resting them.

As a rule an emmetrope having normal acuity will note presbyopic symptoms at about forty-two. They will then have acquired about 0.25 of presbyopia, but if they can read or sew comfortably at a greater distance than $\frac{1}{3}$ of a meter, they will defer wearing glasses for a year or two longer, and then a stronger lens than the above will be required.

Hyperopes become prematurely presbyopic on account of having to use a part of their accommodation to overcome their hyperopia. They will require glasses one year earlier than will an emmetrope for each $\frac{1}{4}$ of a diopter of hyperopia that they possess. On the other hand, for each $\frac{1}{4}$ of a diopter of myopia a patient possesses, presbyopic symptoms will be deferred one year.

Punctum Remotum.

An eye that has a near point of distinct vision (abbreviated p. p.) also has a far point of distinct vision. This is known as its "punctum remotum" (abbreviated p. r.). In emmetropia the p. r. is an infinity, but the p. r. of a hyperopic eye is beyond infinity, and the p. r. of a myopic eye is inside of infinity. The distance between the far point and the near point of distinct vision is known as the "range of accommodation," and the difference between the refracting power of an eye when in a state of rest and when the accommodation is exerted to the utmost, is known as the "amplitude of accommodation."

As stated above, as long as a patient can accommodate comfortably for a distance of $\frac{1}{3}$ of a meter, there will be no presbyopic symptoms, the accommodation being ample, but if asthenopia is present the accommodation should be carefully measured and compared with the patient's age.

Measuring the accommodating power should be a part of the regular routine in refraction work. Often children lack sufficient accommodation to enable them to read or study comfortably. They will present symptoms of presbyopia if any weakness of the ciliary be present. Accommodation may be measured in several ways; the usual way is to note the nearest possible point that fine type can be read, and then measuring in centimeters the distance from the eye that the paper is held. If fine type can be read at 7 c. m., 14 diopters is present, but if 8 c. m. is the nearest at which it can be seen, then $12\frac{1}{2}$ D. is present. 9 c. m. requires 11. D. and 10 c. m. represents 10. D., or the normal amount at the age of twenty.

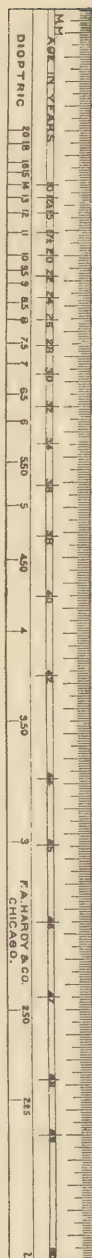
If the accommodation is to be measured by locating the p. p. we shall need some kind of a rule with a metric scale on it, and this rule should give the age in years and the corresponding normal near point for that age as tabulated by the best authorities. Or, what is better, a special rule for this particular method of measuring the accommodating power. Dr. Prince's refraction rule is such a one.

The accommodating power may also be measured and recorded in diopters and fractions of a diopter rather than in distances with any instrument that maintains retinal images which are correct and constant in size, or any instrument that possesses the punctumetric principle of conjugate foci.

The Cross Cylinder Method.

The added power, + or —, required by any patient when reading at their accustomed distance, may be determined by the cross cylinder method of testing for a presbyopic correction. Even the eyes of illiterates may be tested by this method, for only a comparison as to the blackness or distinctness of lines at right angles to each other is necessary.

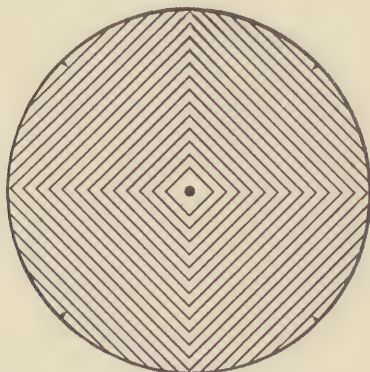
The first step to an understanding of this method of testing is a thorough knowledge of the effect of



placing a cross cylinder before an emmetropic eye, or an eye that has been rendered emmetropic by suitable lenses. With this knowledge the use and value of this method will be clearly understood.

If we place before an emmetropic eye a cross cylinder having $+0.50$ power, axis 180, and a -0.50 power, axis 90, the eye will see the vertical and the horizontal lines of an astigmatic chart equally black and distinct, and the oblique lines will be blurred.

If, when the axis of the $+$ cylinder be placed horizontal before an eye free from astigmatism, we find that the vertical



and the horizontal lines are seen equally distinct, we know that the eye can focus the chart perfectly. But if the lines parallel to the axis of the $+$ cylinder are the blackest, we know that the eye has not sufficient refracting power, and the $+$ spherical lens that makes both the vertical and the horizontal lines equally distinct is the amount that the eye is deficient. If the lines parallel with the axis of the $-$ cylinder are the blackest, we know that the eye has more than sufficient power to focus for that distance, and the $-$ spherical lens that makes both the vertical and horizontal lines appear the same is the excess refraction present.

In such a test the -0.50 cylinder calls for a half diopter of extra accommodation, for the horizontal lines and the $+0.50$ cylinder, axis 180, relieves a half diopter of accommo-

dation for the vertical lines. Therefore if the eye being tested favors either set of lines the lenses are either too weak or too strong.

When making this test the patient should hold the chart at the distance he wishes to hold his paper or do his work. This distance varies somewhat. Some desire to read or work at 30 c. m.; others at 33 c. m., or possibly 36 c. m.

A suitable chart for making this test is illustrated on page 94. The chart should be held so that the lines are vertical and horizontal and the axis of the + cylinder should be parallel to the horizontal lines.

ACQUIRED HYPEROPIA.

At the age of sixty an emmetropic eye begins to acquire hyperopia, and at the age of seventy will have acquired about 1. D., and at eighty, 2. D. will have become manifest, and according to this rule hyperopes will have become more hyperopic and myopes will have become less myopic. This loss of refraction or acquired hyperopia seems to be due to some shrinking process which takes place in all the ocular tissues as a result of old age, or it may be partially due to a lack of nutrition, or to a flattening of the crystalline lens. Either one or all of these may influence the results shown. At the age of sixty the accommodating power has practically subsided, and the eye then begins to lose its natural refraction; the loss being at the rate of 1. D. in ten years, so that at the age of seventy an emmetropic eye will have become 1. D. hyperopic, and at eighty, 2. D. hyperopic. The loss of accommodating power between the ages of twenty and sixty is almost exactly $\frac{1}{4}$ of a diopter each year, so that at the age of forty presbyopia sets in, and if only 60 per cent of the accommodation present at any particular time can be used comfortably, the glasses worn by presbyopes will have to be increased occasionally between the ages of forty and sixty. After the latter age only the acquired hyperopia and the natural loss of acuity due to old age will have to be cared for.

VISUAL ACUITY.

Is the Visual Acuity an Index to the Power of the Spherical Lens Required to Produce 6/6, or Normal Vision?

Dr. Thorington says that under certain conditions it is.

The conditions required are:

First—That the ciliary muscle shall be at rest when the test is made.

Second—That the eye must be capable of obtaining 6/6 vision, or better.

Third—That the test be made at a distance of 6 meters.

Fourth—That any astigmatism that may exist must be corrected with a cylindrical lens before the test for acuity is made.

Fifth—That the test type used shall measure the acuity in tenths of the standard for normal acuity.

Under the above conditions the visual acuity is an index to the spherical lens (+ or —) required to give 6/6 vision and the same lens which will give a vision of 6/6 will also give a vision of more than 6/6, provided the acuity of the eye, being examined, is greater than the standard for normal.

The reason for the fifth condition is that the interval between the different sizes of letters used to test the acuity must be perfectly uniform. Each line must represent exactly one, or more tenths of normal vision. For instance: A 60-meter letter is ten times the size of a 6-meter letter; it, therefore, represents but one-tenth of normal acuity if viewed from a distance of 6 meters; a 30-meter letter would represent two-tenths; a 20-meter, three-tenths; a 15-meter, four-tenths and so on.

It has been demonstrated that for each one-tenth of acuity that the eye is shown to be deficient, it requires a one-fourth diopter lens (0.25) to bring the acuity to normal, or to 6/6.

For instance, an eye that is deficient four-tenths requires four quarters, or one diopter, to bring its acuity to 6/6. If it is deficient seven-tenths, it requires seven quarters, or 1.75, to bring its acuity to normal. We will suppose that a patient seated 6 meters from the test type, can only name the 60-meter

letters. We know that these letters are ten times as large as are the 6-meter letters. They, therefore, represent one-tenth of normal acuity. Such a patient is, therefore, deficient nine-tenths, and according to the above rule would require nine quarter diopter, or 2.25, to raise their acuity to 6/6. If the above rule is practically or even partially true, the time consumed in making the subjective test may be greatly reduced. Not only this, the fatigue caused the patient by a long and tedious examination will also be materially reduced and this ought to enhance the value of the results finally obtained.

If Dr. Thorington and others who have found the above rule to work out nicely, are right—and we have every reason to believe that they are—test charts based upon the above principal become almost a necessity, especially to the busy oculist, for they will enable the doctor to place a lens in the trial frame at once that will practically enable the patient to name the 6-meter letters. According to the above rule, a patient (with accommodation suspended) that cannot name the 60-meter letters, requires a + or — spherical lens of 2.50, or stronger.

VISUAL ACUITY, NORMAL AND SUBNORMAL.

As the question of Visual Acuity enters largely into the correction of all kinds of ametropia, it is well to consider what may be considered normal and what ought to be considered subnormal acuity.

Under the present standard for normal acuity an eye is considered to have normal vision if letters subtending an angle of not more than five minutes at the nodal point can be recognized. In order that such a letter may be recognized each arm and the interval between the arms must subtend an angle of not more than one minute. This standard as embodied in Snellen's types is for an average normal eye, and therefore it is expected that some patients should have greater and others a lower acuity than the average. Thus in youth and middle age, if the conditions are favorable, vision should exceed the average; while later in life a lower standard may be accepted as the average.

It is an established fact that visual acuity decreases with age, and that late in life the acuity is practically but half what it was in youth. For instance, at the age of fifty we may be satisfied with an acuity of 6/6, while at the age of eighty we could hardly expect to find it greater than 6/9 or 6/12. On the other hand, between the ages of 15 and 30 we should not be satisfied with less than 6/5 or 6/4, and if the conditions are favorable it may be as high as 6/3.

If we assumed that vision equalled 6/4 in youth we ought to expect 6/5 at 50, 6/6 at 60, 6/8 at 70 and 6/9 at 80, and if these acuities are recorded we may be satisfied.

These standards are of course for a healthy eye, with corrective lenses if required, and with good illumination. Visual acuity depends largely upon the refractive condition, the age, the receptive and transmissive faculties of the retina and optic nerve and the transparency of the media. The general conditions of life and its environments also may have their effect upon the visual acuity; therefore these should be considered when determining the acuity that a certain patient should have.

If when testing an eye we find subnormal vision as compared with the above standards, it should be our endeavor to discover the cause of the reduced visual acuity. In the first place it is very important that we know whether glasses have been previously worn, and if so for how long a time, and if possible we should know the acuity they gave. With this information we may determine the probable cause of the acuity being low, for if the patient has never enjoyed acute retinal images through non-correction or defective correction, the receptive qualities of the retina have deteriorated for the want of use. This frequently occurs in high degrees of defect such as myopia and astigmatism, particularly the latter, provided the error be of considerable extent.

If anisometropia be present the retinal images in one eye may have been almost entirely ignored, with the result that complete or partial amblyopia has been acquired in one eye.

Sub-normal vision may also be due to opacities or to irregular astigmatism. If the latter be present the pinhole disc, or the Ophthalmometer will usually disclose it at once. Either of the above instruments are very valuable for differentiating between optical and pathological cases.

The great question is what may we call *normal sub-normal* vision as distinct from *abnormal sub-normal vision*. That is, what degree of sub-normality places the case beyond the province of one who is purely a refractionist.

By normal sub-normal vision we mean those cases in which the deficiency is due not to disease but to the permanent lack of sharp retinal images or natural deficiency, and it is here that the refractionist must use his judgment. It is impossible to give any hard and fast rule that should be followed, for each case must be treated upon its own merits. We can, however, give some idea as to the maximum sub-normality permissible, but we must remember that this also depends upon the age of the patient and also upon the time during which the eye has been receiving imperfect images. We may say that the retina of a patient twenty years of age has not had time to lose its sensitivity through disuse unless the error of refraction has been high from early life.

In these circumstances unless the vision is at least 6/6 the

case is not one for refraction only, for the simple reason that in youth our standard is $6/4$ or $6/5$ at the least. If we are satisfied with the latter we are really allowing a latitude of only one line, and this many times is not enough. Again, if the refractive error is so high that it has never allowed normal vision at any distance, the cause is most probably outside the province of one purely a refractionist.

We may therefore generalize by saying that unless $6/6$ vision is attained in persons up to twenty or twenty-five years of age, the refractionist would be wise to refer his patient to a medical man, one skilled in the treatment of eye diseases. Above this age we may generally extend the limit provided we carefully sift the evidence which alone must justify the latitude given. Thus, say at thirty, when vision has been subnormal for some years, we may be satisfied if we obtain $6/9$ or even $6/12$, but, as we said before, no hard and fast rule can be laid down as to what we should consider abnormal subnormal vision.

Of course the refractionist must exclude all possibilities of disease or opacities; in fact he must satisfy himself from the history of the case and the conditions he actually finds that the deficiency in visual acuity is not a sudden one. If any doubt arises regarding the time that the vision has been deficient, he should not hesitate to refer his patient to some one for medical examination.

A point that is often lost sight of in actual testing is the importance of the functions of accommodation and convergence. Too much attention is often paid to obtaining the maximum visual acuity, whereas harmony between accommodation and convergence is of prime importance in every case. Normally the two are conjugate functions; the exertion of a given amount of the one calling for an equivalent exertion of the other, so that any disturbance of this harmony, when the one is stimulated to a greater extent than the other, may lead to asthenopia.

When a pair of normal eyes are adapted for infinity, both the accommodation and the convergence are at complete rest, and if the eyes are orthophoric all the extrinsic muscles are at rest also. In such cases the fixation of a near object de-

mands an exertion of an equal number of diopters of accommodation and meter angles of convergence.

For instance, if the emmetropic patient fixes upon an object one-half meter away, he puts in force two diopters of accommodation, and at the same time he also converges two meter angles. He has then exercised an equal amount of both of these powers, but the hyperope of two diopters must put in force two diopters of his accommodation in order to see distant objects, yet no converging power must be put in force. On the other hand, if he fixes upon an object one-half meter distant he must put in force four diopters of accommodation, which in harmonious vision calls for four meter angles of convergence, yet he must only put in force two meter angles. There is not, then, in such a case that harmonious action of these important functions that there ought to be. Every hyperope accommodates in excess of his convergence whatever the distance of the object.

The internal recti then receives undue stimulus through the third nerve which supplies both muscles, with the result that a condition of Esophoria is usually set up. This, however, is by no means invariably so, because quite often we come across cases of Hyperopia with Exophoria. Exophoria in Hyperopia is, however, nearly always due to inherent weakness of the internal recti rather than undue stimulation of the opposing muscle. Again in Myopia no accommodation is used at the far point, but convergence is exerted to secure binocular vision at all points and to maintain this for all distances convergence must constantly be in excess of accommodation. Now, here there is a lack of stimulus to the ciliary muscles, and the internal recti only fulfill their functions by special innervation which tends to render their action labored and painful. The muscular condition, therefore, we should expect to find in Myopia is that of Exophoria, but while this is the general rule it is not uncommon to find Myopia with Esophoria.

For our purpose we may divide all cases suitable for optical treatment under two main heads, these being muscular and refractive. It is, we think expedient to take some of the muscular cases in conjunction with the spherical element of the correction, since horizontal insufficiencies are frequently

amenable to spherical treatment, whereas vertical and oblique insufficiencies are not.

As we have already pointed out, it is usual to expect Exophoria with Myopia, and Esophoria with Hyperopia, and, other things being equal, the correction of these should be in full. It is, however, when we find Exophoria with Hyperopia and Esophoria with Myopia that considerable judgment must be used. We have to consider whether, in Exophoric Hyperopia the esthenopia is due to ciliary contraction or to the internal insufficiencies, and this again depends upon the amount of the imbalance. Amounts under five degrees rarely cause trouble, so that insufficiencies not in excess of five degrees may not need special consideration, the spherical correction being slightly reduced at the judgment of the refractionist. In some cases where there is marked Asthenopia the spherical element in the formula for lenses may be omitted altogether at the first trial. It is, therefore, a question of reducing the spherical element by anything from 25 to 50 per cent, or giving the full correction, the latter should be given the preference, as the chances are the imbalance will not be troublesome; however, if Asthenopia still continue after a thorough trial, there is no alternative but to reduce the correction sufficient to give relief.

In Esophoric Myopia precisely similar arguments apply, the only difference being that the object is to suppress accommodative action as fully as possible. In Myopia there can be no Accommodative Asthenopia, and in the absence of this or other apparent cause, the discomfort must be caused by the imbalance, and, therefore, it is advisable to commence with a decided undercorrection, the spherical element in the glasses being gradually increased from time to time as the muscles grow accustomed to the new conditions. It should be noted, however, that care must be taken in cases of Esophoric Hyperopia and Exophoric Myopia (i. e., the usual state), not to make a mistake of suddenly applying full correction where none had previously been worn, especially in medium and high degrees of error, for it must not be forgotten that unequal exertion of accommodation that convergence may have

become habitual, and, therefore, sudden equalization of these powers may prove intolerable at first; if such a condition be suspected by the refractionist he should be on the safe side and undercorrect at first, both in Hyperopia and Myopia.

LOSS OF VISUAL ACUITY.

Between the age of sixty and eighty the eye loses nearly 50 per cent of its visual acuity, and this loss as a rule necessitates larger retinal images, provided that the patient reads the same size type as formerly, and the reader to obtain larger retinal images holds his paper nearer to his eyes; he therefore must increase the power of his reading glasses accordingly. If the paper be held $\frac{1}{3}$ of a meter from the eye a 3. D. convex lens will be required to parallel the rays, and this is the usual strength required by an emmetrope at the age of sixty, or by those whose eyes have been made emmetropic by the aid of correcting lenses.

If by reason of loss of acuity, or if the eye be naturally amblyopic (low acuity) the reader must hold his paper nearer to his eyes than $\frac{1}{3}$ of a meter. Such a patient at the age of sixty, having no accommodation, must wear glasses sufficiently strong to overcome all divergence of the rays, no matter how close he has to hold his paper. If he holds it 30 c. m. from his eyes he will require + 3.25; if 28 c. m., + 3.50 will be required; if at 26 c. m., + 3.75, or if he must hold it as close as 25 c. m., a + 4.00 D. will be required. If hyperopia, natural or acquired, be present, the glass that corrects it must be added to the above. On the other hand, if myopia is present the reading lenses may be less than the above.

The accommodation is a great factor to be dealt with when fitting glasses for reading, writing or sewing purposes. The convergence is also an important factor to be considered, especially if the pupillary distance is great and the reading point close to the eyes. In such cases the lenses may be decentered in a little. The effect of this will be to allow the patient to converge to a point, say 33 c. m., while actually holding the paper 20 c. m. from his eyes, patients are often relieved of severe

asthenopic symptoms by decentering their reading lenses in toward the nose. In other words, place the optical centers of the reading lenses closer together than are the centers of the pupils. A frame which is too narrow, provided the lenses are centered, will have the same effect as decentering the lenses.

The amount of decentering necessary to relieve the asthenopia varies according to the pupillary distance (p. d.) and the distance that the work is held from the eyes. If the p. d. is wide and the work held close to the eyes, the converging muscles must be severely taxed, provided binocular vision be maintained. This is especially true if exophoria in accommodation be present, for this only adds to the stress that must be put upon these muscles. If the spherical lenses, which enable the patient to read at the desired distance, do not relieve the asthenopia, prisms, bases in, should be incorporated in them.

The following table gives approximately the presbyopia present at different ages. The age is given in the first column, the accommodation present is noted in the second column, and the amount of this power than can be used for sustained vision is given in the third. The amount of reserve power is noted in the fourth, and the lenses required to correct the presbyopia at $\frac{1}{3}$ of a meter is given in the last.

Age.	Accommo- dation.	Available.	Reserve.	+ Lenses required.
40.....	5.00	3.00	2.00	.00
42.....	4.50	2.70	1.80	+ .25
44.....	4.00	2.40	1.60	+ .62
46.....	3.50	2.10	1.40	+ .87
48.....	3.00	1.80	1.20	+1.25
50.....	2.50	1.50	1.00	+1.50
52.....	2.00	1.20	.80	+1.75
54.....	1.50	.90	.60	+2.12
56.....	1.00	.60	.40	+2.37
58.....	.50	.30	.20	+2.62
60.....	.00	.00	.00	+3.00

TEST TYPE.

The lowest angle under which two points may be distinguished from each other has been taken as a unit of measurement for visual acuity. Hooke found that this angle corresponds to one minute, and Helmholtz later found practically the same angle. For instance, they found that a double star in order to be recognized as such by the eye, must have a separation equal to one minute. Ophthalmologists, therefore adopted this angle as a unit of measurement for visual acuity. An eye that can discern an object under the above angle is said to have normal acuity. Test letters known as Snellen's are based upon this angle. The three limbs of these letters and the two spaces between the limbs each subtend an angle of exactly one minute, the whole letter subtending an angle of five minutes when viewed from the distance named above the letters. Rays of light from an illuminated object that have traveled six meters or more before they enter the eye are practically parallel, therefore, the above distance (six meters) is generally used when making a test for visual acuity or for an error of refraction. The size of a one minute angle when the radius is six meters is obtained in the following manner:

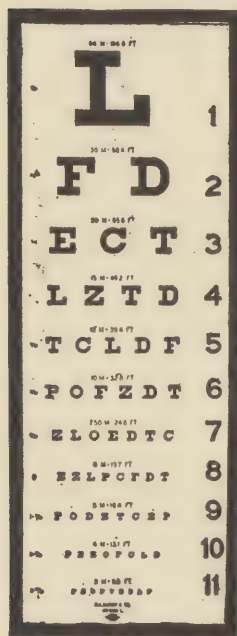
The diameter of a circle, the radius of which is six meters, is twelve meters, or 12,000 millimeters. The circumference of this circle in mm. would be 12,000 multiplied by 3.1416, or 37,699.2000 mm. To get the number of mm. in one degree, the above is divided by 360. We therefore have 104.70 mm. in one degree. One sixtieth of this sum, or 1.74 mm. is, therefore, one minute, and this multiplied by five gives us 8.70 mm. as the size of our standard 6 m. letter. (See illustration.)

The acuity of many eyes, especially those of children, exceeds the standard. There are, also, many eyes the acuity of which falls far below the standard adopted. Therefore, several different sizes of letters are necessary for testing purposes.

An eye possessing only 1/10 of normal acuity would not be able to name a letter that subtended an angle of less than 50 minutes at 6 meters. On the other hand, an eye possessing

normal acuity plus $5/10$ would be able to name one subtending an angle of only $3\frac{1}{3}$ minutes at the above distance.

In order that the visual acuity may be measured accurately and named or recorded comprehensively the interval between



the different sizes of letters should always be the same. For instance, each interval should correspond to one or more tenths of the standard—just the same as every inch on a twelve-inch rule should be of exactly the same length. With few exceptions, this commendable rule has been entirely ignored by publishers of test type. If this rule were followed we would have 200—100—66.66—50—40—33.33—25—20—16.66 and 10-foot letters on a card containing ten lines, instead of 200—100—70—50—40—30—25—20, 15 and 10. The interval between 200 and 100 is exactly $1/10$, but between 100 and 70 it is less than $1/10$, while between 70 and 50 it is more than $1/10$. It is again $1/10$ between 50 and 40, but very irregular between all the other sizes; yet this would not be so bad if all the

letters were of the proper size to subtend an angle of exactly five minutes at the distances designated. We regret to say that much of the test type to be had is far from being correct in this respect—nearly all being from 10 per cent to 20 per cent too large, and also out of proper proportion—the limbs of the letters being too wide and the spaces between them too narrow.

A letter that subtends an angle of fifty minutes at six meters represents exactly $1/10$ of normal acuity; one that subtends an angle of twenty-five minutes $2/10$; one that subtends an angle of ten minutes $5/10$, etc.

To obtain the size of a letter representing $1/10$ of normal acuity we multiply the size of our standard six meter letter by ten. We, therefore, have 87.00 mm. as our standard for $1/10$ of normal. Such a letter subtends an angle of fifty min-

utes at six meters and an angle of five minutes at 60 meters. It is known as a 60 m. letter.

The size of a letter representing $2/10$ of normal is obtained by dividing 87.00 by 2. If we divide by 3 we obtain the size of one representing $3/10$ of normal; if by 4, $4/10$; if by 8, $8/10$, etc. If we divide by 12 we obtain a letter representing normal acuity $+ 2/10$; if by 15 normal $+ 5/10$, etc.

We may also divide the distance 60 m. by 2, 3, 4, 5, 6, etc., to obtain the distance at which each of these letters subtend an angle of five minutes. If we divide by 2 we get 30; if by 3, 20; if by 4, 15 meters, etc. We therefore, have on our test cards 60—30—20—15—12—10 and $7\frac{1}{2}$ meter letters representing respectively 1, 2, 3, 4, 5, 6 and $8/10$ of normal vision.

We also have 6, 5, 4 and 3 meter letters representing respectively normal. Normal $+ 2/10$, normal $+ 5/10$ and normal $+ 10/10$.

A card with letters as above will have eleven different sizes of letters. The smallest of these that the patient can read when seated six meters from the card (which should be well illuminated) represents their visual acuity. This may be named or recorded in tenths of the normal, or as $4/10$, $6/10$ normal, or normal $+ 2/10$, etc. A patient may not be able to read letters representing more than 4 or $6/10$ of normal before correction and normal or better after. Such patients may be informed in terms which they will understand exactly how much their vision may be improved with lenses.

The visual acuity may also be recorded in fractions—the numerator of which expresses the distance of the patient from the test letters and the denominator the number of the smallest ones that can be read. For instance, if the patient is seated six meters from the card (this is the distance generally used), and the 12 meter letters are the smallest that can be read, the visual acuity could be recorded as $6/12$ (the equivalent of $5/10$). If they are able to read the four meter letters, the acuity could be recorded as $6/4$ (the equivalent of $1 + 5/10$).

The former method, however, is far easier to understand, especially by the patient.

Visual acuity may be defined as the amount of vision possessed by an eye after any error of refraction that may exist

has been corrected. However, records should show vision with and without corrective lens. The lithographic process of producing test type is very expensive, yet it has been found by experience that test letters to be perfect must be produced by the above process. In printing from types printer's ink seems to run a little. This makes the limbs of the letters a little too wide and the spaces between the limbs a little too narrow. This is especially true with the smaller letters, and these are the very ones that should be quite perfect.

Ophthalmologists everywhere have recognized the value of the author's test letters based upon an equal interval between the different sizes of letters and this principal is being generally adopted.

The following table shows the visual acuity represented by letters such as are generally found upon test cards—the 20-foot letters representing normal acuity if read from a distance of 20 feet. Note the disparity in the intervals.

$20/200 = 1/10$	$20/150 = 4/30$
$20/110 = 4/22$	$20/100 = 1/5$
$20/70 = 2/7$	$20/50 = 2/5$
$20/40 = 1/2$	$20/30 = 2/3$
$20/25 = 4/5$	$20/20 = 1$
$20/15 = 1 + 1/3$	$20/10 = 1 + 1$

Metric measurements as compared with English feet:

Meters	60.	30.	20.	15.	12.	10.
Feet	196.8	98.4	65.6	49.2	39.4	32.8
Meters	7.5	6.	5.	4.	3.	
Feet	24.6	19.7	16.4	13.1	9.8	

TEST TYPE FOR NEAR VISION.

It is difficult to produce test letters that are correct for use at one meter (40 inches) and more difficult to produce them for use at $\frac{1}{2}$ a meter (20 inches), and still more difficult to produce them for use at $\frac{1}{4}$ of a meter (10 inches), and we might say that it is practically impossible to produce them that are correct for use at $\frac{1}{8}$ of a meter (5 inches). Yet there is need for letters that subtend an angle of five minutes when viewed from a distance of $\frac{1}{16}$ of a meter ($2\frac{1}{2}$ inches). The size of such a letter is $\frac{9}{100}$ of a millimeter. Each arm and each space between the arms of such a letter must measure less than $\frac{2}{100}$ of a millimeter if the letters are correct for a distance of $\frac{1}{16}$ of a meter. A child ten years of age with a normal eye is said to possess fourteen diopeters of accommodation. If we measure this amount accurately with test letters we must use those that subtend an angle of five minutes at $2\frac{3}{4}$ inches. As stated above, it is practically impossible to produce letters small enough to be correct for so short a distance. The smallest test type to be had measures practically $\frac{1}{2}$ mm. Such type is suitable for a distance of 33 centimeters (practically 13 inches) and is suitable for that distance only provided we are to obtain accurate results. If the above type is used for a distance less than 33 centimeters the retinal image becomes too large and the results inaccurate. If we are to get accurate results the visual angle under which the letters are seen must be correct.

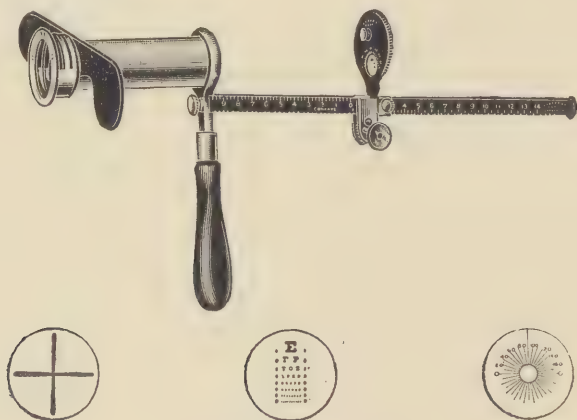
For instance, when six meter letters are viewed from a distance of six meters, the visual angle under which they are seen is five minutes. There is then produced on the retina of the eye the standard size image for normal vision.

The following scale gives the size of letters in hundredths of a millimeter which produce an image correct in size when seen from the distances named:

Distance in Centimeters.	Size of Letters in Millimeters.	Approximate Dis- tance in Inches.
10	.15	4 in.
20	.29	8 in.
30	.44	12 in.

Distance in Centimeters.	Size of Letters in Millimeters.	Approximate Dis- tance in Inches.
40	.58	16 in.
50	.73	20 in.
60	.87	24 in.
70	1.02	28 in.
80	1.16	32 in.
90	1.31	36 in.
1 meter	1.45	40 in.
6 meters	8.73	20 ft.

It will be seen by the above that letters small enough to be seen under an angle of five minutes at 30 centimeters (12 inches) must measure less than one-half mm., and if these same letters are used for ten centimeters (4 inches) the retinal image would be three times the standard size. It will also be seen that letters which are small enough to be correct for ten centimeters (4 inches) could not be seen at 20 centimeters (8 inches), for at that distance the retinal image would be altogether too small.



Punctometer and targets.

If we measure the accommodation accurately we must maintain practically the same size image upon the retina that was produced by the six meter type when viewed from a distance of six meters. If we study the above scale a little, it will be seen that it is practically impossible to do this with type.

It is also practically impossible to measure the accommodation accurately by placing strong concave lenses before the eye and then view six meter letters through them, since the concave glass forms an image of the letters so much nearer in proportion, as it is stronger.

Fortunately, we possess an instrument (the Punctumeter, see illustration), which maintains a retinal image, that is of the correct size, no matter whether the type used as a target is three or thirty centimeters from the eye. Tscherning says (Physiological Optics, page 83) that the principle of this instrument is admirable.

It is composed of a single lens, the focus of which coincides with the anterior nodal point of the eye, the position of the latter being made secure by an eye rest. A diminished copy of a six-meter chart is used as a target. This target is placed beyond the lens and is movable, forward and backward.

It is possible to measure the visual acuity as well as the amplitude or range of accommodation with this instrument. The accommodating power may be measured and recorded even to $\frac{1}{4}$ of a diopter. It is this feature that makes the instrument so valuable to the refractionist.

All authorities agree that in every case the refractionist should obtain a thorough knowledge of the amplitude, or range, of accommodation, as the amount of this power possessed by the patient when compared with their age often reveals conditions that would otherwise escape notice.

The amount of latent or concealed hyperopia is practically always revealed by the above instrument.

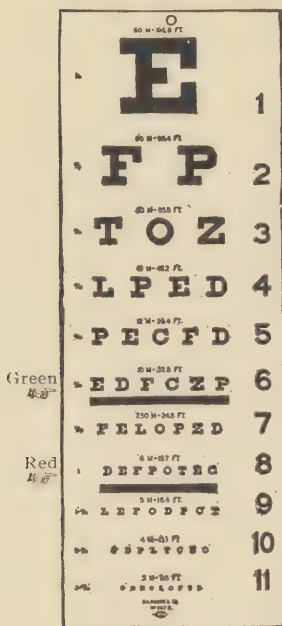
If there is spasm of accommodation it also will be shown.

The refraction of an eye when under the influence of a mydriatic may be measured almost instantly with this instrument. It will also reveal at once the amount, if any, of unsuspended accommodation.

A TIME-SAVING ADDITION TO TEST-TYPE CARDS.

Those who have had much experience in the refraction rooms of large ophthalmic hospitals will recall the difficulty encountered and the time lost in trying to get patients to read the test-card letters in order, or even at all. When a patient is asked to read the lowest line he can, he invariably says: "I can't read the lowest line, doctor!" You ask him to read the letters from the top down, and he reads to the third or fourth

line, then begins to call off the numbers of the lines. Again, when asked to read the third line from the bottom, he says that he can't read it, but later, with a little coaxing, he reads it perfectly well. He was too nervous to count up three lines from the bottom. Many mechanical test-type cards have been devised to meet these difficulties, and they serve very well in the office; but are not so practical for hospital use, because of their complication or expense. Dr. Holbrook Lowell suggested a simple device, which has proved to work equally well in the hospital and in the office. A strip of gummed green paper, 1 cm. wide, is pasted just below the 20-50 line on the test-type card, and a strip of gummed red paper, 1 cm. wide just below the 20-30 line. (See illustration.) These green and red lines on the test-type card,



being between two important lines enable the operator to designate the line he wishes read. In the office, patients usually will voluntarily say that they can read the letters either above or below the red or green line. In the hospital it is seldom necessary to point out the letters, as was often the case before the colored lines were used. There is no confusion when you ask a patient to read either just above or just below one of the colored lines. Experience shows that these colored lines, besides fixing the patient's attention on the letters you wish him

to read, give a useful hint as to the patient's color perception. By actual comparison with the newer test-type cards, having lines indicated by the large numbers, the writer has found that his device of the colored lines is very much less confusing to the average patient. He has therefore been led to report this little device because of his confreres' kindly approbation and enthusiastic use of it, and he hopes that it may serve to eliminate one of the tiring features of clinic and office vision-testing.

[The above article was written by Holbrook Lowell, M. D., Boston, Mass., clinical assistant at Mass. Eye and Ear Infirmary, and is reprinted from the Archives of Ophthalmology, Vol. XXXV, No. 5, 1906, by permission.]

RED LETTER TEST CHARTS.

Mr. E. Leroy Ryer, who first suggested the use of red test objects, in a lecture before the Optometrical Society of the City of New York, October 11, 1911, extracts from which were published in the Optical Journal and Review, says that a hyperopic eye will accept a stronger plus, and that a myopic eye will accept a weaker minus lens, if a test chart, having red letters on a white background is used in place of the ordinary charts, having black letters on a white background, or white letters on a black background.

The reason for this claim is found in the fact that red light is bent or refracted less, when passing through a lens, than are the other colors constituting white light. Violet light having the greatest refrangibility is bent the most.

Between these two extremes (red and violet) are orange, yellow, green and blue, the latter being less than the violet and the orange more than the red.

A physical demonstration proves that white light in passing through a prism is decomposed and results in the formation of a spectrum—the decomposition being due to the different degrees of refrangibility possessed by the various colored elements that form white light.

Red light, because of its having less refrangibility, is focused further from a lens than is white light or any of the

colors which when mixed form white light. An eye that is emmetropic for white light would be myopic if only violet light entered it, and hyperopic if red light only were admitted to it.

To apply the above principles to actual optometric practice we need only to make the test with red letters, in which case we will be dealing only with red light. Mr. Ryer maintains that such letters help; first, to avoid over corrections in myopic cases; second, that in cases of troublesome ciliary activity or spasm of accommodation they enable one to crowd on a more complete plus correction.

He uses for a comparison test two charts, one having black and the other red letters. These charts are identical except for the arrangement of the letters on them. They are placed side by side.

Mr. Ryer says that in working down out of a fog the red letters are invariably distinguished first, whether the fog be artificial, as in hyperopia, or natural, as in myopia. He also says there is no exception to the superiority and greater safety of this red letter test in myopic cases. He also states that better results can be obtained when estimating astigmatic errors if the radiating lines on the astigmatic charts are red instead of black.

ESTIMATING ERRORS OF REFRACTION BY MEANS
OF TEST CHARTS.

There seems to be a considerable difference of opinion among ophthalmologists regarding the desirability of employing cycloplegics as a general routine in refraction work.

It would seem that there are many cases where it is not only desirable but actually necessary that a cycloplegia be introduced if the refractionist is to obtain anything like satisfactory results. For instance, in the case of young children, especially those having strabismus or where the patient is illiterate or feeble minded, and in cases of amblyopia or nystagmus, it would seem that retinoscopy under cycloplegia was the only reliable method for obtaining correct data. There are also a few patients whose statements cannot be relied upon. They also should be refracted under a cycloplegia. In such cases retinoscopy is of great value, yet it is a well accepted maxim that if the patient does not accept the results obtained by the shadow test when brought to the trial case, that the retinoscopic findings had better be disregarded.

Too much reliance must not be placed upon any one method; even retinoscopy is not infallible, owing to difficulties introduced by peculiarities in the aberration of the eye and by our being unable to refract the macula region.

There are many reasons why the use of atropine should be as limited as possible. For instance, the effect of this drug when used in sufficient strength to produce paralysis of the accommodation, lasts from four to ten days and during that time the patient is in a most uncomfortable condition. For this reason, if for no other, its use for business men and others who cannot afford to lose time from their work is clearly out of the question. Homatropine is less objectionable, for its effect usually disappears in 48 hours, yet the same drawbacks are present in each case. These drawbacks are a dilated pupil and a ciliary relaxation greater than ever occurs under normal conditions, and the uncertainty as to the amount of latent hyperopia that should be corrected. In a great majority of cases if the subjective examination be by the now extensively practiced fogging system, there will be no uncer-

tainty regarding the results and therefore no necessity for using a cycloplegic.

Should there be uncertainty there is yet time to place the patient under the influence of atropine. But even then the patient must wait until the effect of the drug has disappeared and another examination has been made before the glasses can be ordered. As a rule the post cycloplegic examination will disclose the fact that only a certain amount of the total error obtained under the cycloplegic can be worn comfortably by the patient. The amount finally accepted will be practically the same as would have been obtained if the fogging method had been resorted to at the beginning.

If the patient be myopic the glasses may be ordered before the effect of the cycloplegic has disappeared, but in such cases the results will be identical with those obtained by the fogging method.

In hyperopic cases where the patient is intelligent and the eyes have been carefully refracted by the fogging method, the results will be as satisfactory as they would have been if they had been examined while under the influence of a cycloplegic or with a dilated pupil, excessive aberration and an abnormally relaxed ciliary.

When the fogging method is used the addition of a convex lens, placed in the trial frame before the eye, of a strength sufficient to blur distant objects to a certain degree, actually forces the ciliary muscle out of commission for the time being, since no effort that it may make to overcome the blur produces clear retinal images. In fact, the slightest amount of accommodative effort only increases the blur. Therefore a condition similar to the cycloplegic state has been produced, the difference being that in one case the ciliary muscle has been paralyzed, while in the other it has been rendered ineffective for the reason given above.

The power of the fogging lens will vary in different cases, but a good plan is to use enough plus to blur distant vision to about 6/12. Thus, if the clearest possible vision be 6/6, we would fog this until it was only 6/12. Too much fogging will not do for the reason that it produces so much blurring that contrasts in the distinctness of the lines on the astig-

matic chart is lost. The lines on the chart used should be about the same width as are those that make up the letters that can be seen under the fog.

The fogging method, by rendering all the refracting meridians myopic, places, as it were, all the lines of the astigmatic chart out of reach of the accommodation. In this way finer and more constant differences in apparent distinctness of the lines are made visible to the patient. The greatest contrast will be observed when the meridian of least refraction is made emmetropic. The blurring or fogging system will be found of equal value in all forms of refractive errors. Almost always some astigmatism will be discovered, and if none is found we may be sure that little, if any, is present—at least not enough to require correction.

When using this method we first determine the strongest plus sphere or the weakest minus sphere that gives us the best vision obtainable; then add plus spheres until the vision is blurred sufficiently. This amount will vary with each individual case, but, as explained above, a good plan to follow, except, of course, where the acuity is low due to something other than an error of refraction, is to reduce vision to about 6/12.

If no accommodation is in force, except the amount that is habitual, or the amount that covers up the latent error, each + 0.25 lens placed before the eye will reduce the vision 1/10. Therefore + 1.25 will reduce it 5/10, or to the 6/12 line. If such a lens does not blur the vision to 6/12 the chances are that the accommodation has relaxed somewhat to overcome the blur, and more plus will have to be added. After the vision has been blurred the required amount the patient's attention is called to the astigmatic chart. The interval between the lines on this chart should not be greater than 10° (Dr. H. C. Parker's modified Verhoeff chart is recommended).

Care should be taken to see that the patient does not endeavor to see better by narrowing his lids, thus producing the effect of a stenopaeic slit, as this might lead to errors in locating the principal meridians.

The blurring should be reduced very slowly by placing minus spheres over the fogging lens until the patient is able

to name a line that is more distinct than the others. When this point is reached the blurring should be reduced with minus cylinders, placing their axes in the meridian of the most blurred line, or at right angles to the distinct line.

The minus cylinder that causes all the lines on the chart to appear equally distinct is the measure of the astigmatism. The blurring is now reduced cautiously with minus spheres until the clearest picture of the letter chart is obtained.

It is a good plan when clearing up the fog to use very weak lenses. The jump should not be more than 0.25 or 0.12, the latter being the best one to use when approaching correction. The interval between the changes should not be too rapid. In other words, the eye should be given time to relax between each change.

If the lines on the astigmatic chart do not remain equally distinct an error has been made.

In the higher degrees of hyperopia the accommodation is active, hence greater blurring is required. In the higher degrees of myopia instead of adding plus lenses we use weaker minus spheres. In other words, we under correct to produce the fogging desired. In such cases the best possible vision with the weakest possible lenses should be the rule.

Mixed astigmatism is as easily determined by this method as hyperopic or myopic astigmatism. The fogging method is also a valuable one to follow when the eye is under the influence of a cycloplegic. The procedure in such cases being the same, but less blurring is required. It is also valuable when preceded by a retinoscopic examination.

A cross cylinder combination trial lens is very useful when this system is followed, plus 0.25 combined with a minus 0.25 with their axis at right angles to each other. When such a lens is used it should be rotated to all meridians of the eye. If a position is found where the vision is improved or where the lines of the astigmatic chart are cleared up, there must be some astigmatism that needs correction. It may not be the total amount of the cylinder (0.50), but there must be some, and the principal meridians must be where indicated by the lens. The cross cylinder when used in connection with the fogging system will be found a helpful lens.

THE METRIC SYSTEM.

The metric system is rapidly superceding the English or inch system of measurement, especially in the optical world.

That all measurements for spectacles and eyeglasses can be more accurately taken, and more easily written in m/ms than by the inch or any other system, can hardly be questioned. The unit of measurement in the metrical system is a meter (M). A meter is divided into 100 centimeters (CM) and a centimeter into 10 millimeters (MM).

There are, therefore, 1,000 millimeters in a meter. It is these millimeters which are being used by the oculist and the refractionist as their unit of measurement for spectacle and eye glass dimensions. If we compare the two systems we find that a meter is practically 40 inches, and that $2\frac{1}{2}$ centimeters is practically an inch, and that three millimeters corresponds to $\frac{1}{8}$ of an inch.

When the dimensions of spectacles or eye glasses are written in millimeters no fractions are ever necessary. For instance, when writing the P. D. in the R we would write 60 instead of $2\frac{3}{8}$ inches, and for height of bridge we would write 6 instead of $\frac{1}{4}$ inch, and for width of bridge at its base we would write 17 instead of $1\frac{1}{2}$ inch. It will be clearly seen that in each of the above instances the dimensions are more easily written in whole numbers than in fractions of a number. Not only this but there is less chance of making mistakes when whole numbers are written than when fractions are.

The advantages then of using the metric system are a uniform series of measurements easily taken and easily written and devoid of opportunities of making mistakes, either in reading or writing them.

When the metric system is used it is never necessary to write "scant" or "full" after the figure, as is often done when the inch system is used. The inch system is not exact enough unless carried out to the smaller fractional denominations, or at least to 16ths of an inch, and this often adds to the chances for errors and confusion. Probably 90% of the R filled by the jobbing houses which are written in the inch system call

for a pupillary distance of $2\frac{1}{4}$ ", $2\frac{3}{8}$ " or $2\frac{1}{2}$ ". Here we have only three dimensions covering considerable space. If they had been written in 16ths of an inch we would have had five dimensions instead of three, and if written in millimeters we would have had seven different dimensions covering the same distance.

Of course the above distances may be correct, but the chances are three to one that they are not, or that the actual P. D. is one m/m more or less than the distance noted.

When low power lenses are prescribed a slight error in the P. D. does no material harm except the cosmic effect; but when high power lenses are worn a slight error in the P. D. is sure to interfere with the angles of vision and thus cause more or less discomfort. The inch system should be as obsolete in noting dimensions for spectacle or eye glass frames or mountings as it is in numbering lenses. The metric system when applied to spectacle and eyeglass measurements gives a very concise statement of the exact dimensions required. A vest pocket rule graduated in centimeters and millimeters is one of the handy tools that every refractionist should not only possess but use.

NEUTRALIZATION OF LENSES.

Lenses have character, form and power.

The character of a lens depends upon the curves given its surfaces. If the master curve be convex the lens is said to be a positive one, and is commonly called plus and designated by the sign "+." If the master curve be concave the lens is a negative one, and is commonly called minus, and designated by the sign "-." The form of a lens may be spherical or cylindrical, or it may be both spherical and cylindrical. It may also be sphero-toric in form. The power of a lens depends upon the radius of curvature given its surfaces, and upon the index of refraction possessed by the glass from which it is made. The power of a lens is expressed in diopters or fractions of a diopter. The smallest fraction in general use being $\frac{1}{8}$ of a diopter, written (0.12-D). In addition to the above forms there is what is known as plano lenses and prisms. The former has flat surfaces or surfaces which lie parallel to each other. The latter form also has flat surfaces, but they do not lie parallel to each other. A prism, therefore, is wedge shape, its thick edge is spoken of as its base and its thin edge as its apex. In writing formula for lenses when prisms are involved the meridian in which the base of the prism is to lie is noted in the formula. Refracting lenses, whether spherical, cylindrical, sphero-cylindrical (or of whatever form) are practically made up of prisms. In the convex variety the bases of the prisms are directed toward and join each other at the optical center of the lens. In the concave variety the apices are directed toward the center of the lens, where they join each other. All refracting lenses, therefore, have prismatic effect. This causes objects viewed through them to be displaced unless the object be seen through the optical center or optical axes of the lens. If a convex lens be moved from side to side in front of an eye the object viewed through it will appear to move, and this movement will be in the opposite direction to the movement of the lens. If the lens be concave the apparent motion will be with the lens. If the lens be moved up the object appears to move up, and vice versa. If the lens be a sphere, the movement will be the same in all meridians. If it

be a cylinder there will be no movement in the meridian of its axis, but there will be movement in all other meridians. If it be a sphero-cylinder the movement will be greater in one meridian than it is in another. These movements, therefore, indicate both the character and kind of the lens, and they also afford a ready means of determining its strength.

A plano lens causes no apparent displacement. Therefore, no movement takes place when such a lens is moved as described above. If we place two spherical lenses of the same power and of opposite sign in contact with each other, with their curved surfaces together and their optical centers coincident, a plano lens will be the result. Therefore when these lenses so held are moved in front of an eye no apparent motion will be noted, the negative refraction of one lens having exactly neutralized the positive refraction of the other. If the power of one of these lenses be known the power of the other is apparent. It is essential, however, that the above conditions, viz., optical centers coincident and surfaces in contact, should be established.

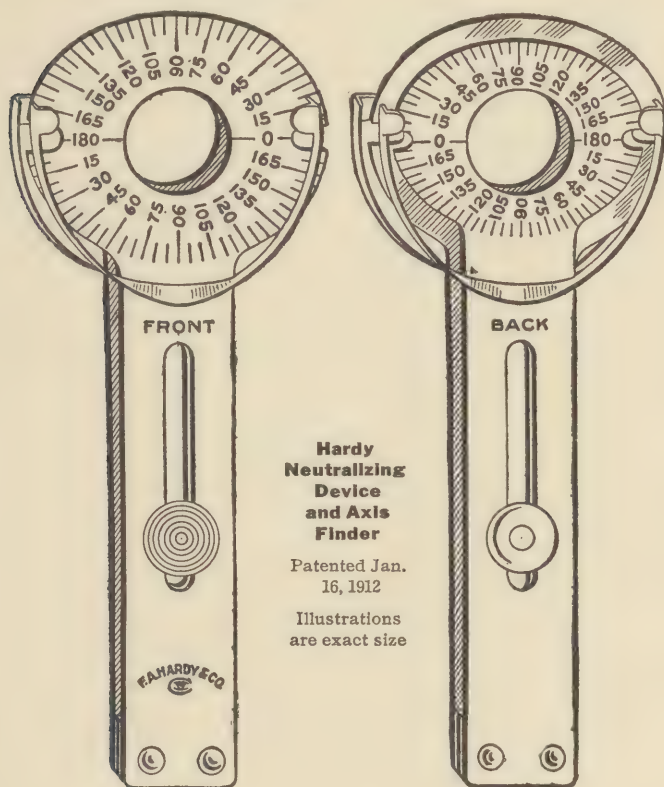
It is apparent that the above conditions cannot be met unless one of the two lenses be plano concave and the other plano convex; and that their curved surfaces are together. The resulting plano lens will have flat surfaces. A bi-convex lens of four diopters placed between two plano concave lenses of two diopters each would also produce a plano lens with flat surfaces; but one each bi-convex and bi-concave would not exactly meet the above conditions, because the outer surfaces would not be plano.

It is not possible in actual practice to always meet the above ideal conditions, but they must be practically met if exact results are to be obtained.

When neutralizing a lens for the purpose of obtaining its power as few lenses as possible should be used; and convex and concave surfaces, whether spherical or cylindrical, should be placed together. The axes of neutralizing cylinders should lie exactly in the same plane.

The low power (0.12 to 8.00 D) spherical lenses of opposite sign and equal strength will practically neutralize each other, even if their positions are not ideal, but high power lenses, or

lenses of low power but having sharp curves, like toric or meniscus lenses, should be neutralized with lenses having curves as near like those being neutralized as possible. Plano concave and plano convex are the most practical forms to be had for neutralizing purposes.



When wishing to determine the power and character of a lens by neutralization, first look through the lens at an object some distance off and note the apparent movement of the object viewed. If when the lens is moved up and down and sideways the movement is in the opposite direction the lens is convex. If the movement is with the lens it is concave. If there is movement except in one meridian it is a cylinder; and the meridian in which no movement occurs is its axis. If the

cylinder be convex the movement will be against. If concave, with. If the movement is greater in one meridian than in another, the lens is a sphero-cylinder; and the meridian in which the movement is least is its axis. If there be no movement it is either plano or a prism.

The extent of these movements indicates the power. Low powers like 0.12 produce but little motion. If the movement is against we select a concave lens from our trial case, and holding the two together move them as before. If there is still motion against, a stronger concave must be chosen; if with, a weaker one. A lens that stops all motion has the same power as the one it neutralized. If the lens in question be concave, a convex is chosen from the trial case. If the lens be a sphero-cylinder, the motion will be stopped in the meridian having the least power by a lens that represents the spherical element, and in the opposite meridian by another. The difference between the power of these two lenses represents the cylindrical element.

When neutralizing cylinders or sphero-cylinders the axis of the cylinders should be dotted to enable the operator to move the lens exactly in the plane of its principal meridians. If we view a straight line through a cylinder or a sphero-cylinder and rotate the lens in its plane, that portion of the line seen through the lens will be tilted more or less, depending upon the extent of rotation and the power of the cylinder. The line will appear straight or continuous when the axis of the cylinder lies either in the same plane as the line or at right angles to it. By this means the principal meridians of a sphero-cylinder or the axis of a simple cylinder may be located and dotted. The lens should be held midway between the eye and the line, which should be at arm's length.

The axis of a cylinder may be located approximately, but not always accurately, by a lens measure. If in place of a single line we draw two lines at right angles to each other we may locate the optical center of the lens as well as the axis. To do this we move the lens about and rotate it until the lines forming the cross are continuous and unbroken. When the lines are straight and unbroken the eye (one eye should be covered) that views them is looking through the optical center,

which should be dotted. If the lens is dotted correctly and the dot is not at the geometrical center of the lens there is a prism incorporated in it. A prism displaces an object in a single direction—the displacement being in the direction of its apex. Prisms of like power neutralize each other when the base of one overlies the apex of the other.

In neutralizing lenses stronger than 8.00 D, unless plano spherical test lenses are used, there will be more or less aberration at the edges. This may be stopped by placing between the lenses a thin piece of black paper with a hole about one centimeter in diameter cut in it. By this means the center of the lens may be neutralized.

When neutralizing toric lenses the test lens should be placed on the outer convex side. If placed on the inside there will be quite a space between the lenses at the center, making it impossible to obtain good results.

Two cylinders of like power and opposite sign will not neutralize each other unless their axes lie in exactly the same plane. The power of such lenses may be more easily obtained if spherical lenses are used and the cylinder moved in the meridian at right angles to its axis.

A clamping device for holding the lens to be neutralized and the neutralizing lenses such as illustrated on preceding page aids materially in obtaining correct results.

The author wishes to state that in considering what is here written upon the subject of Neutralization that he wishes to caution his readers against ever growing to feel that any neutralization that may be done by means of lenses is to be compared in accuracy to that done by the approved focusing boxes used by the responsible and reliable wholesale houses, as the testing by means of such focusing boxes is superior and more exact than can be done by lenses unless exact opposites as to curves are obtainable so as to make plain glass.

PERISCOPIC LENSES.

The concavo-convex form of spectacle lenses was first recommended by Wollaston about one hundred years ago. Since that time their use has gradually increased. This increase has been more particularly noticed since compound lenses have been given this form.

For many years positive (+) periscopic lenses, or those so-called, had but a slight concave surface to be placed next to the eye, but recently there has sprung up a demand for those having a greater or deeper concave surface.

The rule for many years was to grind a concave surface of 1.25 only, but recently the demand is for those having a concave surface measuring six diopters. The recognized advantage of lenses of this configuration is in minifying the defective definition resulting from oblique eccentrical refraction through a lens mounted immovably in a spectacle frame in front of a movable eye.

A concave spherical surface, the radius of which is such as to produce the above power (6 D.), will, with its center of curvature at the center of rotation of the eye, be practically normal to the visual axis at a distance of fifteen millimeters in front of the vertex of the cornea, no matter what direction the eye may be rotated to.

A minus lens having a convex surface of 3 D. and a power of 10. D. will have a concave surface of 13. D. Such a lens, therefore, has about the maximum concavity compatible with the conditions under which spectacles are worn.

If we grind the front surface of a lens convex and of sufficient power to allow a concave surface of from four to ten diopters to be ground upon the other surface, we will have a lens that will conform practically to the above condition. This is true whether the lens is a sphere, a cylinder or a compound, and whether it be plus or minus.

Weak minus lenses are greatly improved by giving them a convex curve for the front, for they then have the periscopic form described above.

The value of plus or minus compound lenses is greatly enhanced by giving them this form, and this can only be done by grinding a convex torodial curve upon the front surface of the lens and a concave spherical curve upon the other side of the lens. Such lenses are known as "torics," getting their name from the shape of one of their surfaces, which is that of a convex or a concave tore, the other surface having a concave or convex spherical curve.

A lens which has a concave spherical curve of about 6. D. is the ideal periscopic lens. Such a lens will allow the wearer to look practically straight through his lenses, whether looking down, as when reading, or looking up, sideways or straight away. In other words, when such lenses are worn the visual line will practically always cut the surface of the lens at right angles.

If we look obliquely through a spherical lense there is an astigmatic effect or the effect of a sphere and a cylinder combined. This causes the retinal image of objects viewed to be more or less distorted, and this distortion materially affects the vision.

The power of lenses, whether plus or minus, having the periscopic form, is represented by the difference between the two curves given their surfaces. By adding plus power to the spherical element of the prescription and then grinding minus power to neutralize the amount added, we produce a periscopic lens.

In the case of spectacle lenses of high power the difference in effective power, as determined by the form of the lens, are too great to be neglected; hence in tentative corrections in high degrees of ametropia it is important to make use of trial lenses of approximately the form, which it is intended to prescribe, and, in prescribing, to specify the values of the two surfaces respectively.

To build up trial lenses in periscopic or other required form the spherical lenses of the trial case should be all of plano-convex and plano-concave configuration. With a complete series of such trial lenses any required combination of spherical

surfaces may be made up of two lenses placed flat to flat in a trial frame. With a full series of plano-cylindrical lenses it is also possible to build up many astigmatic correctons in approximately periscopic form by combining a convex or concave spherical with a concave or convex cylindrical surface.

Anyone who understands the rule of transposing ordinary spheres and cylinders, can equally well calculate formulæ for equivalent toric lenses. There is an unlimited choice of transpositions for this purpose; or, rather, the choice is only limited by commercial considerations, which require that one of the spherical or base curves shall be prescribed of a standard power, say, 3., 6. or 9. D., the 6. D. base being generally preferred and, therefore, commonly stocked by wholesale houses. Taking one of the standard base curves for the starting point, the prescriber applies the ordinary rules of transposition to determine the supplementary cylinder and the sphere, which will be worked to his order to any of the usual fractions of dioptric power.

When to Prescribe Torics.

The principal objects to be aimed at when transposing a sphero-cylindrical into a sphero-bicylindrical lens are as follows: The form best for periscopic effect is to be chosen in accordance with the authoritative rules or tables. Here it may be remarked that to those of us who began to interest ourselves in visual optics twenty or thirty years ago, the original notion of a periscopic spectacle lens was probably that of a dome, next to the eye, concentric with the cornea, or rather the point of mobility of the eyeball. This latter gives, for a glass at the usual distance of 15 mm., a concave dome of 28 mm. radius next the eye—or allowing for thickness of glass, say 27 mm. Taking the center of curvature of the cornea, we should have 23 mm. radius. That these radii are too short, according to modern ideas, will be evident from what has just been said as to the most popular base curves.

The cosmic aspect of the matter is also important; and the question of reflections is worth considering from this standpoint as well as from that of comfort for the wearer of the

glasses, and better protection for the eyes by following their contour. Toric working is of value for leveling down differences of curvature, as between the surfaces of sphero-cylinders; and an additional advantage of this is that it tends to confer mechanical strength with less weight. Returning to the lens as a refractor, we recognize the chief advantage of toricity in the design of astigmatic corrections—for which purpose alone is it essential, so that such a “periscopic” shape may be given as to avoid astigmatism of the lens itself for oblique vision. Another distinct advantage, gained as the lens approaches the symmetrical form devised by Wollaston, is that the magnification is the same for direct and oblique vision—a most important point when astigmatism is to be corrected. Toric lenses should be recommended in practically all cases when astigmatism is to be corrected. As a rule the base curve to be used should be left to the manufacturer.

PERISCOPIC AND TORIC LENSES.

Why They Are Better than the Ordinary Styles.

The meaning of the word periscopic is to look or peer around. This would indicate that periscopic lenses afford the wearer a larger field of vision than do the ordinary convex lenses, and by ordinary we mean the bi-convex and plano convex styles.

It is a well known fact that the line of vision must be at right angles to the plane of the lens if we are to obtain the best results. In other words we must look straight through our lenses if we are to see distinctly. If we look obliquely through a spherical lens we get the effect of a sphero cylinder—the object viewed being elongated in one meridian. For instance, if we look at a circle through a plus spherical lens that has been rotated upon its horizontal axis so that we look obliquely through it, the circle will be magnified more in the vertical than in the horizontal meridian. Therefore, the circle will be elongated or elliptical in shape, the major diameter of the ellipse being at right angles to the meridian of rotation. This fact is easily demonstrated by anyone wearing glasses, or who has access to a spherical lens. This being true, we must look straight through our lenses, or practically so, when looking in all directions, if we would have a flat field, and the flatter the field is the clearer the vision will be. It follows, therefore, that if it is possible to construct a lens that will enable the wearer to look straight through it when looking around, he will have a flatter field and at the same time a larger one, and he will also have clearer vision because of the flatter field.

Periscopic Lenses.

Lenses having the periscopic form have been prescribed for many years by practically all refractionists, especially if they were to be used for all purposes. Plus lenses having this principle have a concave curve ground upon the surface placed next to the eye. The standard inside curve for ordinary peri-

scopic convex lenses is — 1.25. Plus lenses having this curve are more expensive than the bi-convex, but so little that that fact has not materially affected their sale. Recently there has been a demand for a lens having more of the periscopic principle, or a deeper concave curve than has the ordinary periscopic. Such lenses are known as deep periscopic or meniscus lenses. The manufacturers who adopted a — 1.25 curve for the standard on ordinary lenses have adopted a — 6.00 D for the standard curve on the deep periscopic. This is probably the best curve that could have been adopted as a standard to work from, as it coincides approximately with the arc described by the eye when turning in its orbit for the purpose of viewing objects not located directly in front.

Toric Lenses.

As stated above, lenses having the periscopic form have been recognized for years as being superior to other styles, yet owing to the difficulty in grinding and the extra cost of compound lenses having the periscopic principle, they have not in the past been as generally prescribed as spherical lenses having this principle; but manufacturers in America are never satisfied until they are able to supply anything demanded by their customers. Therefore, today many of them are in a position to supply not only the deep periscopic spherical, but also compound lenses having a deep concave curve to be placed next to the eye.



Showing the rays of light passing into the eyes through ordinary lenses.

These new compound lenses which have this principle are known as toric lenses. They get their name from the shape of one of their surfaces, which is the shape of a tore, two convex curves being ground upon one surface, leaving the other to receive the concave curve desired to produce the periscopic form. Ordinarily plus sphero cylinders are simply bi-convex lenses, having none of the periscopic principle.



Showing the larger field given and the rays of light passing into the eye through peritopic lenses.



Showing how much preferable the peritopic form of lens is for reading purposes. The rays of light pass through the lens at right angles and to the best advantage, doing away with the necessity for tipping the head over to get the proper focus when reading.

They can, however, have a periscopic effect in one meridian if desired. For instance, suppose a prescription calls for $+1.00 \text{ s } \subset +1.00 \text{ c}$, axis 90. By transposing this prescription to $+2.00 \text{ s } \subset -1.00 \text{ c}$, axis 180, we are able to obtain some periscopic effect in the vertical meridian, but if we desire to obtain the best possible result we will order such a lens made toric. It will then have a toric convex surface for the front and a concave spherical surface for the back. The toric curve will then be $+6.00$ in one meridian and $+7.00$ in the other, and the spherical curve will be -5.00 . Such a lens, if worn for a short time, will demonstrate to the wearer the value of the periscopic principle. Such a lens is more difficult to grind, and therefore more expensive; but they are now being prescribed by many refractionists with gratifying results.

So far we have only touched upon the value of this form of lens for obtaining a larger field. There are several other reasons why they are superior. One is that they look better; another is they may be placed closer to the patient's eyes, for the deeper curve allows room for the eyelashes, and this position again improves the vision, for the reason that the lens curves back towards the eye rather than away from it, making the distance between the pupil and that portion of the lens through which the wearer looks practically always the same, whether looking sideways or straightaway. This distance is more nearly preserved when the periscopic form of lenses are worn than when other forms are used. This deep minus curve is also especially advantageous when cement bifocal lenses are prescribed, for it is possible to so place the scale that the

patient will look practically straight through the lenses when reading.

There are several other reasons why toric lenses are to be preferred over any other style. First, the strong convex curves given the toric or deep periscopic lens act something like the stop or diaphragm found in the eyepieces of most optical instruments, in that they reflect or cut off many of the peripheral rays which cause color and spherical aberration, thus causing more or less confusion in the eye. This light that is cut off is, of course, lost, but the result is a sharpening of the image; therefore, clearer vision. Second, the periphery of toric lenses being closer to the eye and curved back towards it, does not interfere with vision when looking down as much as does the periphery of the ordinary styles. Third, lenses of this style can, as a rule, be ordered larger, especially if they are rimless, than in other styles. Fourth, toric lenses remove to a great extent the reflections which annoy so many persons, which is still another advantage.

SPECTACLE LENSES—THEIR SIZE, SHAPE AND WEIGHT.

For several years there has been a steadily growing demand for larger lenses than were formerly used in spectacles and eyeglasses. The reasons for this are that a larger field of vision may be obtained with larger lenses and that they make a better appearance. In addition to this the modern or so-called saddle bridges used on spectacles afford more space for the lenses than did the old style curled, or C bridges.

The modern, or rimless lense, now so popular, and the toric form, have also contributed their share towards creating a demand for larger lenses.

Lenses are numbered as follows: 4-3-2-1-0-00-000 0000 and Jumbo, and usage has made the term 1 eye, 0 eye, etc., the proper method of description. The two smaller sizes 4 and 3 are now obsolete and the 2 is used only for very small children. We can therefore consider the 1 eye a small lens and the 000 eye a large one. The 1 eye size is 37 mm. long, and is suitable for a pupillary distance (P. D.) of from 50 to 56 mm. The 0 eye is 38.5 mm. long and is suitable for a P. D. of 54 to 60 mm., while the 00 eye being 40 mm. long is suitable for a P. D. of from 58 to 64 mm. The 000 eye is 41 mm. long and is suitable for a P. D. of from 60 to 66 mm. The 0000 and Jumbo sizes are seldom used except by golfers or for eye protectors.

The numbers 1, 0, 00 and 000 may be considered the standard and useful sizes; the 1 and 0 for children, the 0 and 00 for female adults, the 000 for male adults and 0000 for patients with very large features, or wide pupillary distance. The size of the lenses should always be in keeping with the size of the face, and the interpupillary distance.

The spaces occupied by the bridge of a spectacle, or the mounting of an eyeglass, must always be considered when deciding what size lens to prescribe, as this space and the length of one lens should always equal the pupillary distance. For instance, suppose the pupillary distance is 63 mm. and the total length of a bridge which fits the patient correctly, or the distance between the inner edges of the lenses of an

eyeglass when it is adjusted on the patient's nose, is 23 mm., then the lenses must be 40 mm. long. In other words, the total length of one lens and the total distance between the two lenses when they are adjusted on the face, should always exactly equal the distance between the centers of the pupils. (P. D.)

Bifocal and rimless lenses should be one size larger than would be chosen ordinarily for use in frames, and torics should be a size larger than ordinary rimless, or two sizes larger than rimmed lenses; when a large lens is desired it may be provided for by bending the shanks of a saddle bridge in, and for each mm. they are bent in, the length of the lens should be increased 2 mm. The space between the inner edges of the lenses when a saddle bridge is used should never be less than the width of the bridge at its base. If the shanks are bent in too much the spectacle is unsightly. The same result may be obtained by using a short stud on an eyeglass frame or mounting. An A stud being 1 mm. shorter than the regular, or B, enables each lens to be 2 mm. longer than could be used with the regular or B stud.

Large lenses are necessarily heavier than small ones, therefore lenses should not be unnecessarily large, especially if eyeglasses are to be worn, as the extra weight has a tendency to cause the glasses to fall off. If a patient with a thin nose and a wide pupillary distance desires eyeglasses, the size of the lenses may be reduced by using a C or D. stud in place of the regular. The C being 1 mm. longer than the B, allows the lens to be 2 mm. shorter, and the D being 2 mm. longer decreases the size of the lenses 4 mm. each. There is also a stud known as E which is 3 mm. longer than the B, but this is very seldom used.

High power lenses, especially those above ten diopters, whether $+$ or $-$, are necessarily heavy and their weight increase rapidly as the size of the lens is increased, therefore such lenses, if a large eye is desired, should be made lenticular in form, as the weight of this style is about one-third less than the ordinary double convex or concave styles. Convex lenticular lenses are made by cementing on to a light

plano lens, or plano cylinder; provided a sphero-cylinder is desired, a small convex scale to give the desired power.

Concave lenticular lenses are made in two different styles—one known as round and the other as oval. The round style is made by grinding upon one side of a plano, or plano cylindrical lens, a concave surface to produce the desired power. The depression occupying a space of about 22 mm. in the center of the lens.

Oval lenticular lenses are made by grinding a concave surface upon the cylindrical side of a strong plano convex cylinder. This causes the periphery of the depression to be oval instead of round, thus enlarging the field, reducing the weight and improving the appearance of the lens all at the same time. If a sphero-cylinder is desired the original lens would have been a cross cylinder, or a toric instead of a plano cylinder. If the convex cylinder has the proper curve the periphery of the depression will correspond almost exactly to the shape of the lens. Oval lenticular lenses represent high art in spectacle lens grinding. Their weight is only about half as much as it would be if the same power and size were made in the ordinary double concave form.

Thin or light lenses are far more desirable than thick or heavy ones, especially if they are for eyeglasses. Of the bifocal styles, the cement is the lightest and the opifex is the lightest of the cement styles. They, like the oval lenticular, represent high art in lens grinding.

It should be remembered that the shape of lenses, whether rimless or rimmed, may be changed without changing the size of the eye. For instance, the standard size 00 eye is 31 mm. wide and 40 mm. long. If this lens were 32.5 wide and 38.5 long, it would fit the same frame and would then be known as a short oval lens. When it is desirable to change the shape of a standard lens to a shorter or longer one it is only necessary to remember that there must be added to the width the same amount that is taken from the length, or vice versa. Short oval lenses are decidedly popular, especially for bifocals and torics. They enlarge the field in the vertical meridian; they also enable a patient with narrow P. D. to wear larger lenses.

When rimless lenses are prescribed they may be made the exact width and length desired, or they may be made delta or leaf shape, thus giving a greater field for reading purposes, or they may be made half eye or crescent shape, short or long, oval, etc. The crescent style is very acceptable to presbyopes who require no distance correction.

SPECTACLE LENS MOUNTING.

After the oculist or optometrist has made his diagnosis and written his formula for lenses designed to correct an error of refraction or to replace lost accommodation or to correct an anomaly of the ocular muscles, comes the by no means simple question of suitable frames or mountings to hold the lenses in a correct position before the patient's eyes. We say correct position because a faulty one would probably destroy any good effect which the most carefully chosen correction might produce. Not only this, a faulty position of a lens or lenses might introduce a fresh source of eye strain. If so, discomfort and dissatisfaction must naturally follow.

The lenses must occupy a correct position before the patient's eyes if the best results are to be obtained. Not only this, they should be mounted so they will inconvenience the wearer as little as possible. We say inconvenience because it is inconvenient to wear glasses, and if this inconvenience more than outweighs the beneficial results obtained by their use, they will not be worn.

Attention should be paid to the personal appearance of the wearer; if possible the spectacles or eyeglasses should improve rather than detract from his personal appearance. The wearer of glasses should be better pleased with her or himself when he has them adjusted, than he is without them.

For the above and many other good reasons, the mounting of lenses is of the greatest importance. A few of the questions which naturally arise and which should be settled before the measurements for frames or mountings are taken are these:

Are the glasses to be worn constantly, or only for close work?

If constantly, is presbyopia to be provided for?

If so, are bifocal lenses to be worn, or two pairs of glasses supplied?

If bifocal lenses are chosen, which style will most likely please the patient?

The patient's face, and especially the nose which must carry the spectacles or eyeglasses, must be carefully considered, his or her age, occupation and desires, the material of which the frames or mountings are to be made, and whether eyeglasses or spectacles are to be chosen; if spectacles, whether riding-bow or straight temples; if riding-bows, are they to be cable or solid wire; if eyeglasses, what style of guard will hold the lenses correctly and securely in position; are the lenses to be mounted in frames or made frameless? These and many other important questions arise, and they ought all to be settled before the oculist takes his measurements for frames or mountings.

We will suppose that the patient is a child: if so, framed spectacles with hook temples must be chosen and they should be made of gold; no other metal is suitable for a child. If the patient is an adult his choice as to style of frames or mounting may be considered. The oculist should always keep in mind his responsibility and exercise his influence to the end that a suitable frame or mounting be chosen, one that will serve the purpose well. What was said in regard to children, applies to a few adults, yet as a rule they may be allowed to choose between spectacles or eyeglasses or between rimmed or rimless lenses, especially if spectacles are chosen.

The modern idea of rimless lenses is a good one, especially since the dispensing opticians are now furnishing mountings for either spectacles or eyeglasses which are both neat and serviceable. They are to be had in all kinds of material at about the same prices as frames. The modern eyeglass, thanks to the inventors, may now be prescribed with confidence; in many cases they will serve the wearers better than would spectacles. This is especially true if they are to be worn intermittently. Eyeglasses may as a rule be more easily adjusted than are spectacles, and when carried they occupy much less space in the pocket. Eyeglasses having plain or flexible guards, are

very serviceable for presbyopes or for those desiring to wear them only for close seeing. After the question of style, material, etc., has been settled upon, comes the question of measurements: if riding-bow spectacles have been chosen ten measurements should be taken and noted, preferably in the order named below:

- 1st. Interpupillary distance.
- 2nd. Size of eye.
- 3rd. Height of bridge.
- 4th. Width of the bridge at its base.
- 5th. Inclination of the crest of the bridge in relation to the back plane of the lenses.
- 6th. Angle of the bridge's crest.
- 7th. Angle of the joints or end pieces.
- 8th. Width between the temples one inch back from the joints.
- 9th. Length of temple to back of ear.
- 10th. Total length to temple.

The first four of the above ten measurements should be noted in every prescription written for spectacles, for without these measurements there must be more or less guesswork on the part of the person building the spectacle and we might say right here that nothing should be left to guesswork. As a rule, the manufacturing opticians are good guessers, but their guess may be wrong. There are standards for angle of crests, angle of joints, length of temples, length of bridge, shanks, etc., and if these standards are known to be correct for the patient being prescribed for these dimensions may be omitted from the prescription. For instance, the fifth dimension may be omitted, provided the standard position of crest ($1\frac{1}{2}$ mm. forward) allows the lenses to occupy the desired position in front of the eye. The sixth may also be omitted provided the standard angle of crest (45 degrees) lies perfectly flat on the patient's nose when the temples rest upon the ears. The seventh may also be omitted provided the spectacles are for constant use and that the lenses occupy the desired position vertically when the temples rest in their proper place. The eighth is important only when the distance between the temples of a standard frame

which has the correct pupillary distance is too wide or too narrow for the patient's face. The ninth is important if the standard length of temple (6") is too short or too long to look well or be comfortable. The temples needed may be either short (5"), medium short (5½"), long (6½"), or extra long (7"). If the tenth measurement is noted, a temple may be furnished that will, when properly curled, be perfectly comfortable.

The length of a riding bow temple from joint to back of ear may be altered by curling it between thumb and finger. The curl at the top should be rather abrupt and the tip should be turned back a little. This prevents the ball at the end from irritating the ear.

Of the ten measurements given above the first, or the interpupillary distance, is the most important. This will be understood when it is known that the decentering of a pair of one diopter spherical lenses 5 mm. each produces 1° prism. If a pair of 5 D. lenses are decentered 2 mm. each, they produce a 2° prism, and if this decentering is such as to produce hyperphoria to the extent of even ½ degree the result may be great discomfort.

If the distance between the centers of the pupils is known and the optical and the geometrical centers of the lenses exactly coincide, it is possible to so mount them in a frame or eyeglass that there will be no prismatic effect. If the optical centers of the lenses are too wide apart, they will excite strain on the internal recti muscles, and if they are too close together, they will cause strain of the external recti muscles. In either case there would be discomfort attending their use. The optical centers of the lenses must be in the same horizontal plane also, if they are not, the effect of a prism base up before one eye and base down, before the other, is produced. This causes the inferior rectus muscle of one eye and the superior rectus muscle of the other eye to do abnormal work, thus causing strain and therefore discomfort. A pair of lenses may be perfectly centered, yet when placed before the patient's eyes, their optical centers may be too far apart or too close together. This in effect is the same as decentering the lens itself; thus it will be seen that they should be, not only per-

fectly centered, but also correctly mounted. In fact, the lenses should be as nearly as possible a part of the eyes which they are to assist.

As stated above, the first and most important of the above measurements is the pupillary distance (P. D.). This is best taken with a small vest pocket rule (see illustration), measuring from the inner edge of the pupil of one eye to the outer edge of the pupil of the other.

If the glasses are for constant use, the patient should be looking at an object some distance beyond the operator when the measurement is taken. The operator should hold the rule in his right hand, letting it rest upon the patient's nose with its upper edge just below the pupils, and one end at the inner edge of the pupil of the right eye. Then note where the outer edge of the pupil of the left eye comes (or the edges of the iris may be used); by this method very exact measurements can be taken, especially if the operator will close his right eye



when placing the rule and his left when noting the P. D. If the glasses are for reading, or close work only, the patient should be allowed to converge to the reading point when the measurement is taken.

It is a good plan when measuring the P. D. for reading glasses to hold the index finger of your left hand in front of your forehead and the rule at arm's length. Then direct the patient to look steadily at the upheld finger while you note the P. D. The distance between the centers of the segments on bifocal lenses should be the same as the P. D. when reading. If a patient requires high power lenses great care should be used when taking this measurement. The best results will be obtained if the distance is noted in millimeters. If the P. D. is great, say, 70 mm. ($2\frac{3}{4}$ in.), the converging muscles are taxed more than they are when the P. D. is narrow. Good results are often obtained by decentering the lenses in a little, or the frame may be a trifle narrow. The effect of this is to allow the patient to converge to a point beyond where the work is actually held.

The second measurement to be noted is the size of the lenses (eye). It has become the style, and it is a most excellent one, to prescribe the largest lenses possible or compatible with the patient's features. There are several good reasons for wearing large lenses. They afford a larger field and make a better appearance than small ones do. Their lower edges do not interfere with vision when looking down as much as do the edges of small ones. Lenses are known as 1, 0, 00, 000 and 0000. All of these sizes are useful: The size 1 for children; 0 for female adults or those with small faces, and the 00 and 000 for patients with medium and large features, and the 0000 for those with very large features. The two larger sizes are very popular with sportsmen and golfers. The length of the above lenses (rimless) is as follows: 1 eye, 37 mm.; 0 eye, 38 mm.; 00 eye, 40 mm.; 000 eye, 41 mm.; and 0000, 44 mm. Short ovals are $1\frac{1}{2}$ mm. less than the above.

In determining the size most suitable for a patient we must consider the thickness of the nose and the interpupillary distance. If the nose is thick and the P. D. narrow the lenses should be made short oval. Such lenses will afford a larger vertical field than would the regular oval. They are also very useful when bifocals are worn.

Toric and rimless lenses should be especially large. We should remember when deciding as to the size of eye that the total length of one lens and the distance between the inner edges of the two lenses must exactly equal the P. D. If we do we will have little trouble in determining the size to prescribe. For instance, suppose that the distance between the inner edges of the eye wires of a spectacle frame, the bridge of which fits the patient correctly, is 20 mm. and the P. D. is 60 mm.; we simply say $60 - 20 = 40$.

Therefore, our lens must be 40 mm. long.

Rimless lenses may be made any length or width desired.

If the lenses are to be mounted in an eyeglass, a sample eyeglass should be placed upon the patient's nose and the distance between the lenses noted while in that position. This distance plus the length of one lens should equal the P. D.

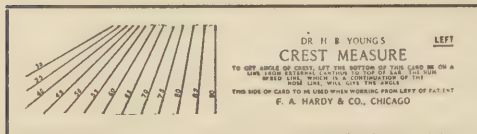
The third, fourth, fifth and sixth measurements are known as bridge dimensions. The first of these is the height; the

second the width at base, the third the inclination and the fourth is the angle of crest. The first three of these dimensions are most easily determined by the use of trial frames with bridges of known dimensions. These three dimensions are all important, as upon them depends the position of the lenses and in a measure the comfort of the patient. The height of a spectacle bridge that is to be worn constantly may be said to be correct if the patient looks through the center of the lenses when looking at the floor ten feet away. If the glasses are to be used only for close work the bridge should be two or three millimeters higher. This will allow the lens to drop low enough to allow the wearer to look through them just below their centers when reading. The height of a spectacle bridge is the distance that its crest is above a line drawn through the centers of the lenses. If both lenses lie in the same horizontal plane the prismatic effect produced by looking through them above or below their centers will not cause trouble, because the bases of both prisms are either up or down. The second of the bridge measurements is the width at its base. This should be the same as the thickness of the nose at the point where the bridge wire bends away from it. If the width is right the bridge will rest comfortably and the weight of the spectacles will be distributed over as much space as possible. If it is too wide all of the weight will be carried by the crest of the nose. If too narrow the lower points will indent themselves into the sides of the nose. Either of these will be likely to cause discomfort.

The third of the bridge measurements is known as the inclination of its crest. This measurement is very important, for upon its position depends the position of the lenses in relation to the eye lashes. The lenses should occupy a position as close to the eyes as possible and not touch the lashes. There is a point upon practically every nose where the bridge ought to rest. The crest of the trial bridge should be placed at that point and the position of the lenses in relation to the lashes determined. If the lashes sweep the lenses the shanks of the bridge should be increased in length just sufficient to allow them to clear. If there is space between the lashes and lenses the shanks should be shorter. In other words, the crest of the

bridge may be inclined farther forward. Saddle bridges are now almost universally used. They are made with three different lengths of shanks, known as "regular," "long," and "extra long." With the regular shanks the crest of the bridge is inclined $1\frac{1}{2}$ mm. forward of the back plane of the lenses. The long shanks place the crest and the lenses on the same plane, while the extra long shanks place the crest $1\frac{1}{2}$ mm. back of the plane of the lenses. These positions are known as plus (forward), 0 (on line) and minus (back). L. S. refers to long, and E. L. S. to extra long shanks. A bridge with regular shanks is always supplied if no inclination is noted in the prescription. The fourth of the notations as to the bridge refers to the angle of its crest which should lie perfectly flat upon the nose. If it does not either the upper or the lower edge will cut into the nose. Bridges as now made are slightly rounded upon the lower side. This rounding of the lower surface prevents cutting provided the nose has practically the same angle as the bridge crest; but if the angles are not practically the same, either the lower or the upper edge will cut. If the angle of the nose is 70° and the angle of the bridge is 45° (the standard angle), the upper edge will surely cause discomfort, for a nose with the above angle will allow the spectacle to drop down unless the temples have considerable pull. This pull is sure to cause the upper edge of such a bridge to cut, and if the temples do not pull a little the spectacles are sure to drop down. But if the crest of the bridge is angled to 70° so that it lies flat on the nose, the pull of the temples will not cause any cutting. The standard for crest angle is 45° and if the nose does not vary but a little from that it will

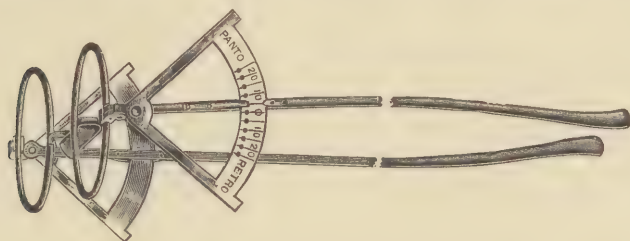
rest comfortably; but it may need to be practically horizontal or nearly vertical to be comfortable.



The angle for bridge crest may be approximately obtained by the use of Dr. Young's Crest Cards. (Directions for using them are printed upon the cards.) They may be obtained gratis from the jobbers in optical goods. (See illustration.)

The exact angle may be obtained with a Crest and Angle Measure. This instrument is useful also to obtain the amount that a lens should be pantoscopic to be correct for reading. It also measures the angle if the lens must (see illustration) be retroscopic which is sometimes the case; as when the patient's ears are set high. It also enables the operator to obtain the angle of joints where one ear is lower than the other, so that the spectacle when adjusted will be perfectly horizontal.

The seventh measurement to be noted is the angle of the joints or end pieces. If the spectacles are for constant use, and the ears are in a normal position, the joints will not have



to be angled; but if the ears are too low in relation to the eyes, the lenses will tip out at the bottom and the patient will look under them when looking down. In such cases the joints should be angled down (known as pantoscopic) 5° or 10° . This will bring the lenses to the desired position vertically.

Occasionally the ears are too high. If this is true the lenses will tilt back at the bottom and the patient will look obliquely through them when looking at distant objects. In such cases the temples must be angled up. The lenses are then known as "Retroscopic." The Angle and Crest Measure mentioned above measures for both of these adjustments.

The lenses may be said to be in a correct position when the line of vision is at right angles to their plane.

The eighth measurement to be noted is the temple distance, i. e., the distance between the temples, one inch back of the end-piece, or where they would practically come in contact with the face. Spectacle temples that are properly fitted stand out a little when opened as far as possible, and when in this position they should just touch the face. They will then steady the

spectacles, and prevent them from being moved by a slight jar—as when walking.

The pressure against the face should not be great enough to cause a depression, or discomfort to the wearer. If the pupillary distance is narrow and the face wide, the end-pieces of the frame, or mounting, should be made extra long, thus throwing the temples further apart at the joints and providing more space between them. Sometimes a large eye is used to get this extra width, but this is wrong, for such lenses would have to be decentered if the optical centers coincided with the interpupillary distance.

The cosmic effect of such an adjustment is not good for the reason that the wearer of lenses should look through the geometrical center of them when looking at distant objects. As a rule, the temple distance will be practically correct if a frame—that has the correct size of eye and length of bridge—is used.

The ninth measurement to be noted is the length of temple to back of ear. This measurement is the distance from the inner edge of the end-pieces to the center of the curl at the back of wearer's ear. Great care should be given to this measurement, unless the oculist desires to make the adjustment himself.

A temple that is exactly right will not pull on the nose or on the ear, but will be just long enough to hold the glasses in position without undue pressure on either.

This adjustment may be made by curling the temple between the thumb and finger.

The curl at the top of the ear should be quite abrupt, and from this sharp bend down it should conform to the contour of the ear, or as near so as possible. The ends of the temples should be bent back a little, so that the little balls on them will not irritate the ear. If the tips of the temples are pear-shaped this bend at the end may be omitted.

The tenth measurement to be noted is the total length of temple. What are known as stock temples are 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$ and 7 inch. They are designated as "short," "medium short," "regular," "long," and "extra long." Regular temples (6-inch), are always supplied if no dimension is noted in the

prescription. The end of the temple should come nearly to the lower edge of the ear, but never below it. If a temple is ordered that is the right length, it may be curled as described above, so that it will hold the spectacles in the correct position without causing discomfort.

There are several styles of temples which are designed to give relief to those patients who unfortunately have to wear heavy lenses, or who have sensitive skin. The style known as "cable" are more flexible than those of solid wire, but they have a habit of getting out of shape easily, and when a temple is out of shape it does not properly fulfill its function. Of the numerous styles of cable temples, those known as half cable are probably the most satisfactory.

The so-called "comfort temple" and its half-sister, the "Velvet-tip," are quite popular. They are of the half cable variety; they are larger than the regular cable, and therefore, present a broader surface to the ear.

There are also several styles of ear shields which may be applied to the temples for the purpose of preventing irritation. Probably the most comfortable shield that can be applied is rubber tubing—a piece $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long, being slipped over the end of the temple. Such tubing will not last many months, but can be renewed from time to time at practically no expense.

If a patient who should wear spectacles insists upon wearing eyeglasses (and this is often the case), it is a good rule to prescribe two pairs; one of them being a riding bow spectacle for general use, and the other an eyeglass to be worn only on special occasions. This rule if followed will prevent them from going to someone else to be fitted with a mounting suited to their taste.

EYEGLASS LENS MOUNTING.

Modern eyeglass frames or mountings with their various styles of guards, springs and studs may be so constructed and adjusted that they will serve as a suitable mounting for nearly every adult, but there are a few who must wear spectacles, especially if the error of refraction be great—lenses heavy, or occupation such as to practically preclude the idea of wearing an eyeglass even if they have an appropriate nose for such a mounting.

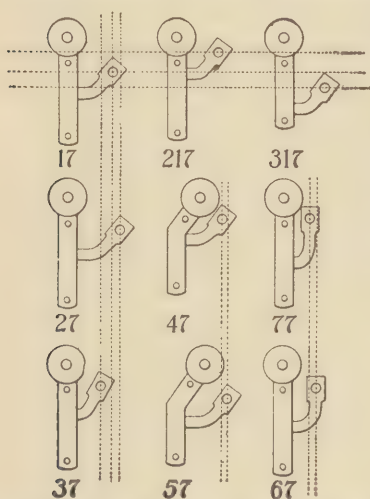
Rimless spectacles will often please a patient (if their beauty and merits are properly presented) who would not consent to wear a rimmed pair. The rigid bridge, or finger-piece eyeglass mounting, now so popular, and deservedly so, may be prescribed with confidence in a large percentage of cases, provided, of course, that the refractionist exercises care in his choice of style and dimensions, and a little skill in adjusting them to the patient's nose. There is more in the adjustment of an eyeglass than is generally admitted. An expert will adjust one to nearly every patient. They, of course, usually have access to and know the value of the various styles of springs, guards, studs, etc. This, of course, is a great advantage, but with a few well chosen samples and a little practice in adjusting the average refractionist will be able to place an eyeglass that will be satisfactory upon nearly every patient who desires one.

The springs, studs and guards of an eyeglass take the place of the bridge of a spectacle. They must be of such design and be so adjusted that they will hold the lenses securely in position. Not only this, the position of the lenses must be correct; correct as to pupillary distance; correct as to height, and also correct as to inclination. It is a simple proposition to obtain the desired pupillary distance by using lenses of different lengths, or by substituting short, long or extra long studs for the regular ones. The correct height may be obtained by using certain guards, or by drilling the lenses above, on, or below the center. The adjustment for inclination may be obtained by using guards, the arms of which are of different lengths or angles; or by using offset studs.

By referring to the following illustrations of guards it will be noted that certain styles raise the lenses, and that others lower them; also that certain shapes hold the lenses farther from, or nearer to the eye than others do. Of the guards illustrated the one numbered "17" is the standard shape. Its arm is attached to the body of the guard at its center, is of medium length and standard angle (30 degrees). No. 217 is the same as No. 17, except that its arm is attached $2\frac{1}{2}$ mm. higher up on the body of the guard, thus raising the lenses that amount.

The reverse is true of No. 317. The arm of this guard is attached $2\frac{1}{2}$ mm. lower down; therefore, the lenses are dropped that much.

As stated above, No. 17 is the standard for both height and inclination. If the lenses are to be inclined, or held, farther from the eye, a guard with a longer arm should be used. No. 27 is such a guard; its arm is 2 mm. longer than the arm of No. 17, and, therefore, it holds the lenses that much farther from the eye. No. 37 has a shorter arm. It holds the lenses



nearer to the eye than does No. 17. No. 47 and No. 57 also have different lengths of arms; so also has No. 67 and No. 77. It will be noted that the arms and the bodies of the two latter lie in the same plane. The lenses when mounted will also lie in the same plane as the guards. Such guards are used on noses that are nearly straight—up and down—or those, having an angle of 60 to 70 degrees.

No. 47 and No. 57 are suitable for thin or flat noses, or those that have to be gripped well forward. For this reason the tops of these guards are angled forward.

Of the above three adjustments—viz., pupillary distance, height and inclination—the first is the most important. This distance (pupillary distance) is best measured with a vest

pocket rule, measuring from the *inner* edge of the pupil of the right to the outer edge of the pupil of the left eye. If the glasses are to be worn continually, the patient should be looking steadily at an object, 10 or 15 feet away; if for reading only, at an object held at the reading distance.

The operator should hold the rule in his right hand, letting its flat surface rest upon the patient's nose, its upper edge being just below the pupils.

REGULAR STUDS



OFFSET STUDS



He should stand practically in front of the patient and should close his right eye when placing the rule and his left when noting the pupillary distance. It is well to remember that the pupillary distance must be exactly equaled by the length of one of the lenses and the distance between the inner edges of the two lenses, when the eye-glass is adjusted on the patient's nose, we, therefore, place a sample eyeglass—which should be carefully chosen—on the patient's nose, and then measure the distance between the lenses, or eye wires, while it is in that position. This distance plus the length of one lens must exactly equal the pupillary distance. Thus it will be seen, that it is a simple proposition to obtain any pupillary distance desired by using lenses of different lengths. Patients having the same pupillary distance will have different noses—some will be thin, others thick—and the pupillary distance of patients having the same thickness of noses, will also vary greatly. This necessitates using lenses of different lengths—and possibly long, or

short studs. If the nose is thin and the pupillary distance wide—which is often the case—it is better to increase the distance between the lenses by using long studs than to use extra large lenses for the reason that large lenses are necessarily heavy and are, therefore, more likely to fall off. If the nose is thick and the pupillary distance narrow, a short stud should be used. If short studs are used the length of the lenses may be increased 2 mm. for each millimeter that they are shorter than the standard—which is known as “B.” If long studs are used, the lenses may be 2 mm. shorter for each millimeter that the studs are longer than the standard. If the nose is not located centrally between the two eyes, studs of different lengths will be required, for the center of each lens should be held correctly before the eye it is to assist. If one eye is more pronounced than the other, and it is found desirable to place the two lenses on a different plane, an offset stud may be used on one side *only*. Offset studs may also be used to secure inclinations that cannot be obtained without them.

When ordering offset studs, it should be stated whether the lenses are to be held away from, or close to the eyes. The former position is known as “inset” and the latter as “outset.”

There are numerous styles of eyeglass guards, but as a rule the simplest ones are the most practical; they are the easiest to adjust, and they keep their shape better after they are adjusted than do the complicated ones. The refractionist who confines himself to a few of the best styles and learns how to adjust them, will, as a rule, obtain good results.

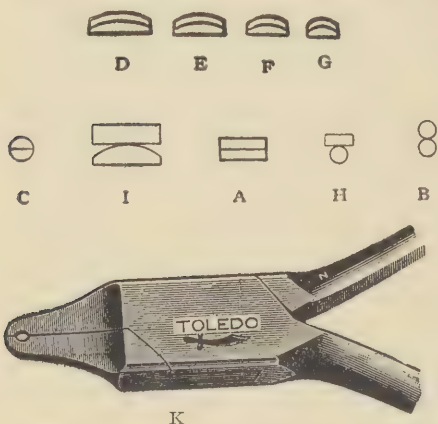
The practical guards are the “Wells’ Anatomical,” “Anchor,” “Pivot,” “Titan” and the “Lasso.” The “all-metal” ones, or those faced with shell, are the best for they may be curved or shaped to almost any form desired, while those lined with cork cannot be. Those made of metal *only* are known as “sanitary” guards; they are very practical.

It requires considerable skill to adjust the guards and the spring of an eyeglass, but those refractionists who acquire this skill are more than repaid for the time spent in acquiring it.

The man who adjusts eyeglasses, or spectacles, needs a few pliers and these should be finely finished—all the sharp corners

being rounded off and polished so that they will not mar the frames.

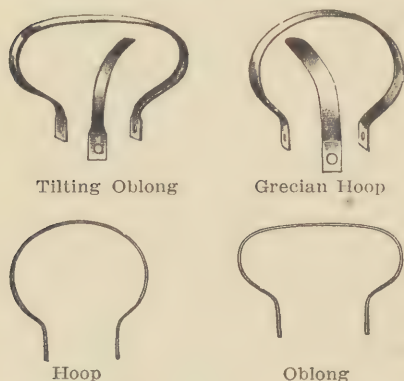
The illustrations above show the styles recommended. The beginner should have at least four (B. C. D. and K.) and he



should add others to this assortment from time to time until his assortment is complete.

The illustrations of studs shown in previous article are full size, so that they may be measured with a millimeter rule. The offset styles are of two dimensions, one being offset $1\frac{1}{2}$, and the other 3 millimeters.

Besides the studs illustrated, there is a style known as a "drop stud." They simply drop the lenses two or three millimeters lower than do the regular styles. The regular and offset styles are made in five different lengths as illustrated. Those known as "box" are far superior to the old style, for the reason that they hold the guards and spring more securely thus preventing the stud screw from working loose. There



are many styles of eyeglass springs, the oblong and hoop styles illustrated above being the most popular. These are made in several different lengths and both styles are made offset, Grecian or tilted. The latter three styles all accomplish the same result, viz., they allow the lenses to set more nearly vertical without the spring touching the forehead, than do the regular styles. These off-

ting styles are of two dimensions, one being offset $1\frac{1}{2}$, and the other 3 millimeters.

set styles are very useful if the eyes are set deep in the head, or if the forehead is prominent. Eyeglass lenses like spectacle lenses should occupy nearly a vertical position, but the springs should never rest on the forehead. Any of the above springs may be obtained either of the same width throughout, or reduced in the center. The latter styles are the neatest but they are more easily put out of shape than are the full width styles.

When adjusting an eyeglass, you should see that the guards lie perfectly flat upon the patient's nose. They should touch at all points but should grip the nose a little harder at the top than at the bottom. If the brow be raised, it will be noticed that the nose narrows up at the top but remains the same width where the bottom of the guards rest. This is the reason that eyeglasses fall off when the brow is raised.

Several of the modern styles of guards have provided for this narrowing of the nose at the top; such guards have a spring embodied in them which acts at the top only, so that when the brow is raised, the spring presses the tops of the guards closer together, thus retaining the grip. There is more flesh and fewer nerves at the top of the nose than there is further down, where the bottom of the guards rest. This extra flesh allows the guard to get a firmer anchorage. Among the guards having this extra *grip feature*, may be mentioned the Anatomical, the Lasso, the Titan and the Spiral. As stated above, the entire surface of the guards should rest on the nose. This often necessitates curving the face of the guards, so that they have the same curves as the nose has.

If the nose has a wide base and a narrow top (wedge shape), the guards must be flared back, or out, so that their surfaces rest flat on its sides. For such a nose, the wide faced guards, or those having large bearing surfaces are the best. The spring of an eyeglass should not be stronger than is actually necessary to hold the glass in position. If the spring is too strong, it will force the glass off the nose. The lenses of an eye-glass like those of a spectacle should lie perfectly horizontal, especially if cylindrical lenses are worn. Therefore the springs and guards must be so adjusted that they will hold them in that position. The adjustment for this position lies both in the spring and the guards. The outer ends of the lenses may be

thrown up by bending the spring close to the stud and by bending the guards closer together at the bottom. Either one, or both, of these adjustments may be necessary.

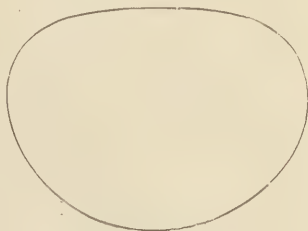
If we wish to bring the outer ends of the lenses down, the bends are made in the opposite direction. It is often found that a shorter, or a longer spring will aid in making this adjustment.

The Concave-convex Pliers (D style) are used to curve both the guards and the springs; the C style to bend the arms of the guards. The Stud Pliers (K style) are used to hold the eyeglass safely when setting up the screws that bind the guards and the spring to the studs.

The two most important points in fitting eyeglasses are the centering of the lenses and the grip on the nose. And it is not always an easy matter to get both of these exactly right, especially if rimmed lenses are to be worn. Such lenses are necessarily of a certain size, but they may have different ovals and yet fit the same rim. This varying of the ovals, or length of the lenses, together with the different lengths of studs, enables the operator to get practically what he wants. It is not so difficult to obtain the correct pupillary distance if rimless lenses are to be prescribed, for they may be made any length desired. The grip of the guards is quite important, and this must be regulated somewhat by the shape and condition of the nose. There are many noses that any guard will hold the lenses securely on, and there are also noses that no guard yet devised will stay on. Therefore, no rule will hold good in all cases, but if just the right guard and spring are chosen, and both are properly adjusted, satisfactory results will be obtained in nearly all cases. The spring pressure should be just right. Too much pressure is as bad as too little, and too much guard is also as bad as not enough. The main thing is to get these two just right, so that the weight of the glasses is just balanced by the pressure of the spring. The spring should not be too short. If it is it will soon lose its elasticity, and will then fail to hold the lenses securely. The guards should be curved so that they touch the nose at all points. They should also lie perfectly flat on the nose. The top of the

guards should press somewhat harder than the bottom. All-metal guards, or those having shell faces, are the most easily shaped. They are to be preferred, also on account of their being more sanitary than are those faced with cork. The lenses should be thin and not too large, for large lenses are heavier than small ones; therefore, more easily thrown off. Light lenses for eyeglasses are preferable from every point of view.

If bifocal lenses are to be mounted in an eyeglass, great care should be exercised to see that both segments are on the same horizontal plane; that they are not too large; and are properly centered. The tops of the segments must be well below the pupils when the wearer is looking at distant objects. It is not always necessary or desirable to use lenses of the regular oval shape. For instance, if the eyebrow overhangs the eye the lenses should be made what is known as A, B, or C style. The top of these lenses is cut away so that they do not touch the brow. No harm can be done by doing this, for the top of the lens is used but little. On the other hand, it is often desirable to add to the lower part of the lens somewhat by making it delta or leaf shape. (See cut of leaf shape.) It then affords a wider field for reading purposes.



Leaf or "A" Shape Lenses

Wearers of eyeglasses or spectacles appreciate every little advantage given them by a lens that is the best shape and size possible.

OPHTHALMIC LENSES.

Various forms of lenses are used for ophthalmic purposes. They are known as spherical, cylindrical, prismatic, spheroprismatic, cylindro-prismatic, spherocylindro prismatic, cross cylinders, sphero torics and torics. The shape given the surface of lenses, together with the angle dividing their two surfaces gives them their name. The simple or commoner forms, are the spherical. These are known as plano convex or concave, bi-convex or concave, and periscopic convex or concave. Convex spherical lenses are segments of a solid sphere, and are known as positive or plus lenses. Concave spherical lenses are segments of a hollow sphere, and are known as negative or minus lenses. Plano convex and concave are produced by grinding a spherical curve, either convex or concave, as desired, upon one side of the lens, and a flat surface, known as plano on the other. The bi-spherical style have a spherical curve upon both sides. Usually both curves have the same radius, so that both sides are alike.

The periscopic are the most complicated of the spherical forms, one curve being convex and the other concave, the radius of one curve being shorter than the radius of the other, the curve having the shortest radius determining whether the lens is positive or negative (plus or minus). A positive periscopic lens is known as convexo-concave, and a negative periscopic as a concavo-convex lens. Cylindrical lenses are segments of a cylinder. The positive, or plus, are segments of a solid cylinder, and the negative, or minus, are segments of a hollow cylinder. When a cylindrical curve is ground upon one side of the lens and the other side is plano, the lens is known as a plano cylinder. If a cylindrical curve is ground upon both sides, the curves being at right angles to each other, the lens is known as a crossed cylinder. If the curves are not at right angles to each other the resulting lens would be an oblique crossed cylinder; practically a sphero cylinder. When one side of a lens has a spherical curve and the other side a cylindrical curve the lens is known as a sphero-cylinder. When two cylindrical curves are ground upon one side of a lens and the other side is plano

the lens would be a segment of a torus. Such a lens is known as a toric. A lens having a toric curve upon one side usually has a spherical curve on the other. It is then known as a sphero-toric. (Usually written toric.) Toric curves like spherical and cylindrical may be either convex or concave, thus producing positive or negative lenses (plus or minus). Prisms are wedge shape lenses, having plano surfaces. When one or more spherical curves are ground upon a prism it is known as a sphero-prism. When one side of a prism has a spherical and the other side a cylindrical curve, the lens is a sphero-cylinder prism. When one side of a prism is curved cylindrically, the lens is known as a cylinder prism. Toric and sphero-toric lenses may also be prismatic. The thickest part of a plus and the thinnest part of a minus spherical lens is known as its optical center. If the optical and the geometrical centers of a spherical lens do not exactly correspond the lens is a sphero-prism. The thickest meridian of a plus and the thinnest meridian of a minus cylindrical lens is known as its axis, and in the meridian of its axis the lens is a plano.

The axis of a cylinder, like the optical center of a sphere, should coincide with the geometrical center of the lens. If it does not the result is a cylindrical prism. Sphero prisms and cylinder prisms are practically decentered lenses. Cylindrical, sphero-cylindrical, toric and sphero-toric lenses practically always have different refracting power in different meridians, and the meridians having the least and the greatest refraction are known as the principal meridians. These two meridians are at right angles to each other; therefore, such lenses having astigmatic refraction are suitable for correcting astigmatism. *The periscopic form of lenses when used for ophthalmic purposes have so many advantages over the ordinary styles that the leading ophthalmologists of the world have been demanding that the opticians furnish not only spherical lenses having this form, but also cylindrical, sphero-cylindrical, toric and sphero-toric; in fact, there is a great and growing demand for ophthalmic lenses of every possible power and combination having this principle.*

High power astigmatic lenses, when used to correct cases of aphakia, should be ground sphero-toric in form. The spher-

ical curve should be sufficient to produce practically half of the power desired in the meridian of greatest refraction, and the toric curve sufficient to produce the remaining power desired in both meridians. Such a lens will have various advantages over its sphero-cylindrical equivalent. By this method the extreme spherical curvature on the anterior surface of the lens may be lessened, thus doing away with internal reflections, which interfere materially with good vision. The weight of the lens is also reduced to the minimum. The use of the sphero-toric lens should not be confined to cases of aphakia, since equally good results may be obtained when high power concave lenses having astigmatic refraction are desired. High power plus lenses, when made sphero-toric, as described above, do not have periscopic form, but approach that form as near as is desirable. High power minus sphero-toric lenses do have the periscopic form, and this form may be given to all sphero-toric and cylindrical lenses, as well as to sphericals. Lenses having this form afford the advantage when placed before the eye of allowing the peripheral area to be brought nearer to and more concentric with the eyeball than is possible with the ordinary sphero-cylindrical or cylindrical forms, so that for all ordinary motions of the eye the visual axis will be less oblique to the inner surface of the lens. The position and the consequent absence of reflection from the inner concave surface also give this form of lens a wider, flatter and more natural field of vision than is obtained by the ordinary styles. This feature alone is sufficient to warrant the use of this form for all lenses that are to be worn constantly. A further commendable feature is that this form of lens can be made thinner, and therefore of less weight, than is ordinarily possible. When cement bifocal lenses are made in this form the segments for reading are confined to an angle more closely approaching position for perpendicular incidence of the visual axis when looking downward. The most advantageous concave curves which produce the periscopic effect are from four to ten diopters. Spherical lenses having a concave curve of six diopters are known as deep periscopic, and for practical purposes this curve furnishes a fair standard to work from. Sphero-toric, whether simple

cylinders or sphero-cylinders, when ground periscopic in form, should have a concave curve approaching the above standard for deep periscopic. Although sphero-toric lenses are considerably more expensive than are the ordinary bi-convex or bi-concave forms of compound lenses, it is fair to predict a decided increase in their application by competent oculists and optometrists as soon as their advantages shall have become more widely known.

Some time since the writer of this article suggested that ophthalmic lenses having a toric curve upon one surface and a concave spherical curve on the other, thus giving to them the periscopic form, should be known as "Peritoric." This name has been generally adopted (although copyrighted by F. A. Hardy & Co.) and is applied to all lenses which have both toric and spherical curves.

The great superiority of the Peritoric form of lenses when bifocals are to be made is vividly shown in the following formula:

The prescription calls for cement bifocals, and is as follows:

Right eye: $+ 3.00$ sphere $\subset + 0.50$ cylinder, axis 180.

Left eye: $+ 3.00$ sphere.

To the above must be added three diopters to correct the presbyopia.

A pair of lenses must practically match if they are to look well. They should be practically the same thickness at their edges and of the same general form.

The above $\mathcal{R}$ calls for one sphero-cylindrical and one spherical lens. If we grind the sphero-cylinder as the $\mathcal{R}$ is written, one side will have a convex spherical curve of three diopters and the other side a convex cylindrical curve of 0.50 diopters. This makes a bi-convex lens, but in appearance it is a plano convex. Therefore its mate, the spherical, should be a plano convex. The scales which are to increase the spherical power from three to six diopters must be cemented to the side of the lens which is curved spherically. They will, therefore, have to have a concave curve of three diopters on the side that is to be cemented to the distance lens. This concave curve will

exactly neutralize the convex curve given the distance lenses. Therefore the other side of the scales must have a convex curve of six diopters to produce the power called for in our R . Both our distance and reading lenses when completed will be practically plano convex.

Now, if the rule of placing the side of the lens having the greatest convexity away from the eye is followed the scales will be on the front or outside of the lenses; therefore away from the eyes.

The anterior surface of our distance lenses would be three diopters, and for the reading lenses, six diopters.

The posterior surface of both would be practically plano.

Such construction would be the best that could be made, provided the R was filled as written. It would be impossible to place such a pair of lenses before the patient's eyes, so that both distance and near vision would be good. If we tilt the lenses sufficient to allow the patient to look straight through them when reading, and they must look straight through them if good results are to be obtained, they could not have good distant vision, or if they are correctly adjusted for distant seeing, they would prove very unsatisfactory for reading purposes. Not only this, bifocal lenses with scales on the outside are very unsightly.

If we ignore the above rule and place the scales next to the eye, we would still be unable to adjust the lenses so that the patient would have satisfactory vision for both distant and near work.

If the sphero-cylinder of the above R is given the peritropic, and the sphere the periscopic form, the posterior surfaces of both may be exactly alike, and the anterior surfaces will appear to be alike. Therefore the lenses will match nicely. Both lenses will possess the periscopic form. The concave curve which produces the periscopic effect may be five diopters, provided $+ 8.00$ base curve is used. On such a lens the scales may be placed next to the eye. They would be ground $+ 5.00$ upon one side and $- 2.00$ upon the other. Both the upper and the lower lenses would have the periscopic form, the upper having $- 5.00$ D and the lower $- 2.00$ D curve.

Such lenses may be placed close to the eyes. They may be

so mounted that the wearer will look practically straight through them when reading, or when looking at distant objects they will afford the wearer a flatter and larger field of vision than the other styles.

The periphery of the lens being closer to the eye and curved back towards it will not interfere with vision when looking down as much as does the periphery of the other styles. They can be made larger than the others. The distance between the cornea and that part of the lens through which the wearer looks will be much more nearly maintained than it would be with the other form.

When bi-convex or plano convex cement bifocal lenses are worn the joints of the frames must be angled down 10° or 15° in order that the reading lenses may occupy the desired position vertically. This is entirely unnecessary when Peritoric lenses are worn.

Theoretically and optically this is far superior to angling the temples or joints, as the fault of obliquity is not only in the vertical, but in the horizontal and all other meridians as well.

The tilting of the lenses for the purpose of getting them into the correct position for reading will interfere materially with distant vision.

The cosmic effect of the peritoric form is far superior to that of the ordinary style.

The advantages to be gained are a flatter and greatly enlarged field; much better vision because of a flatter field; much better position especially for the periphery of the lenses; freedom from annoying reflections from the posterior surfaces of the lenses; larger lenses affording a greater range of vision; distance between lenses and cornea practically maintained when the eye is looking in different directions; maintaining a fixed amount of refracting power because of a fixed distance between cornea and lens; superior cosmic effect; scales at right angles to line of vision when reading; distant lenses correctly adjusted and no angling of joints or temples.

LENSES MADE OF COLORED GLASS.

In treating the subject of colored glass, it is assumed that the student is familiar with light and has some knowledge of the spectrum.

White light is an equal mixture of all the colors of the spectrum ranging from red at one end of the spectrum, to violet at the other end.

Rays of light longer than those producing the sensation of red, are termed "Infra-red" or heat rays, and are invisible to the eye.

Rays of light shorter than those producing the sensation of violet, are termed "Ultra Violet Rays," and are also invisible to the eye.

Heat rays, although invisible, produce irritation and are, on good authority, one of the causes of cataract.

Ultra Violet Rays produce irritation, florescence and when strongly in excess will produce burns that will completely destroy the vision.

Colored glass may, for convenience, be classified into two divisions, viz.:

Glass of High Transmission.

Glass of Low Transmission.

Glass of high transmission may be either a glass having but a slight tint or it may be a glass having high transmission for all colors other than those it is desired to absorb.

Glass of low transmission is glass which, while acting more strongly on some rays than on others, reduces the intensity of all rays to a considerable extent.

Glass of high transmission is necessary where great acuity of vision is desired or where the light is normal or below normal.

Glass of low transmission is necessary where the light is intense and much above normal, as, for instance, in looking into furnaces, electric welding, etc.

To give the student some idea of the action of colored glasses, let us project a spectrum from an arc light by means of a prism or a diffraction grating on a screen coated with anthracene which has the effect of converting the short ultra

violet wave lengths, otherwise invisible, so that they may be seen.

It will be observed that the colors are projected in order of their wave lengths, namely, first: Red, the longest visible wave length; then Orange, Yellow, Yellowish-Green, Green, Blue-Green, Blue, Blue-Violet, Violet, the shortest visible wave length. Beyond the violet is noticed a pale Bluish Green Florescence caused by the action of Ultra Violet light upon the anthracene. The Infra-Red or heat rays cannot be shown upon the screen and must be studied by delicate thermometers.

If we select a deep or intensely red glass and place it in the path of the rays producing this spectrum, we will notice a decided change. While the red rays are all as plainly visible as before, the yellow and all other colors, including violet, have been absorbed and the spectrum has been shortened by two-thirds its length, showing that the red glass has not imparted its red color to the rays passing through it, but has actually cut out or absorbed all the other rays but red.

If this experiment is tried with other glass of different deep or intense colors, it will be found that—

Yellow will pass both green and red, absorbing all the violet.

Green will pass green only, absorbing both red and violet.

Blue will pass both green and violet, absorbing red.

Violet will pass only violet, absorbing both red and green.

Magenta is a mixture of red and violet rays and is not found in the spectrum and by subjecting it to the above experiment, it will be found to pass both red and violet.

Smoke glass absorbs all colors to a greater or less degree, depending upon the density of color.

From the above experiments, it will be noted that the yellow glass has the greatest absorption for the violet end of the spectrum; that the blue has the greatest absorption for the red end of the spectrum.

If a lighter tint of the above glass be used instead of a deep colored glass, it will be observed that while all the colors are visible, the colors which had previously been absorbed by the deep colored glass are now only partially absorbed.

If glass of low transmission is selected for the test, it will be seen that all colors are absorbed, to a considerable degree, but some are acted upon more than others.

In the former condition, some colors were acted upon slightly and others not at all.

In the latter, all colors were acted upon but some more than others.

The latter condition can be imitated by combining a neutral smoked glass which acts equally upon all colors with a colored glass until the desired reduction is obtained.

When the yellow glass is placed in the path of the rays, the florescence, caused by the action of the ultra-violet light acting upon the anthracene, disappears as well as the violet. This shows that the ultra violet as well as the violet, has been absorbed.

If a blue or violet glass be placed in the path of the rays, the florescence still remains showing that the ultra violet has not been absorbed.

This indicates that the glasses having the strongest action upon the ultra violet are those of orange, yellow and yellow-green colors.

The glass having the greatest action on the red and infra-red is green, blue-green and blue.

Since the orange, yellow and yellow-green rays are the rays giving the greatest retina stimulus, glass of these colors or tints should be used where it is desired to cut out the violet glare without reducing the acuity of vision.

Where the use of glass, which will cut down the illumination is indicated (as in welding, etc.), glass of low transmission should be used.

The desirable color for such special uses is produced by combining the effects of a neutral smoke in the make-up of a colored glass otherwise having the desired action on the spectrum.

Glass of all colors, tints and more or less neutral combination is now procurable and pamphlets and information descriptive of the various colors and tints that are used as an aid in correcting defects of vision may be obtained from any wholesale optical house.

BIFOCAL LENSES.

The present great popularity of spectacles having two powers, one for distant seeing and the other for close work, known as bifocals, is largely due to the improvement in their manufacture. Not many years ago the wearing of spectacles implied a certain age, but since they are now worn so generally by both young and old persons the wearing of them has ceased to imply any particular age, unless it can be seen that the lenses worn have two powers.

The evolution that has been going on for several years in the manufacture of these lenses has been to the end that a bifocal lens may be produced that shall have the line of demarcation between the two powers practically invisible, and to produce a lens that shall be free from defects such as prismatic errors, cement breaking, etc.

It is said that Benjamin Franklin was the first person to wear bifocal lenses. This honored American required convex lenses to correct his distant vision and in his later years he required stronger ones to work or read with. It seems that he conceived the idea of having two pairs of lenses mounted in a single frame. He, therefore, instructed his optician to split a lens that corrected his distant vision through its horizontal center and to place one piece in the upper half of each eye wire of his spectacle frame, and to also split one in like manner which corrected his near vision and to place them in the lower half of the eye wires.

This arrangement practically gave him two pairs of spectacles in a single frame and enabled him to see both distant and near objects without changing his glasses. It is said that he wore them for many years with great satisfaction.

This style of spectacle was for a long time known as "Franklin Glasses," but later became known as "split bifocals." This style when well made are quite practical. In the better grades the lower lenses are beveled on one side and the lower half of the eye wires bent back at the end piece and bridge so that the lower lenses will lie at right angles to the line of vision when reading. By this arrangement both upper and lower lenses may be adjusted correctly. The line

dividing the upper and lower lenses of this style is quite conspicuous, it being quite impossible to keep the lenses clean owing to their being of different thickness and of uneven curvature.

The second attempt to produce a bifocal lens was to make what is known as a "solid" bifocal. This was done by grinding a convex curve that would correct the distant vision upon one side of the glass, and upon the other side grind a convex curve which when added to the other one would produce the power required for reading. A flat or plano surface was then ground upon the upper half of the latter side, thus doing away with the power produced by that curve in this part of the lens. This style of lens never became popular. The prin-



cipal reason for this was the great amount of prism produced by grinding the plano surface. (See sketch.)

The third style of bifocal lens placed upon the market was produced by cementing a thin wafer like lens to the lower half of a lens that corrected distant vision, the wafer lens adding the extra power desired. This style became known as cement bifocals and at once became popular. These lenses when well made are free from prismatic errors. They are light in weight and are easily kept clean. They may be made in any desired power or combination of powers. The wafers or scales can be made of any size or shape desired by the wearer. There seems to be but two objections to this style of bifocal; one being the visibility of the scale and the other to the cement breaking. The former is practically overcome by making the scales quite small and exceedingly thin. Such scales are produced by a patented process. Their edges are like the edge of a keen blade, and when they are cemented to the main lens they are quite invisible. This style of lens is known as the "Opifex Bifocal."

The greatest objection to the cement style seemed to be the visibility of the scale or wafer, and to overcome this a lens was produced, the scale of which was made of flint glass, which fitted into a depression ground in one side of the distant lens. The curves given the depression and the scale being the

same, except one being convex and the other concave, they could, therefore, be cemented together. By this method both surfaces of the finished lens was made perfectly smooth. But this lens did not prove to be just what was wanted; "an invisible bifocal." Later a thin plano lens was cemented, or, if a sphero-cylinder was wanted, a plano cylinder over the surface bearing the scale. This gave a bifocal lens, the scale of which was hidden between two lenses. The name "Kryptok," meaning "a hidden eye," was given to this style of lens. This Kryptok lens was, of course, a cemented lens. It, therefore, had its faults as did the other styles, for this, like the others, would become discolored and had to be recemented, which in the case of the original Kryptok was an expensive operation.

These objections both of visibility and cement breaking were finally overcome by the present day Kryptok lens made as the original Kryptok was made, but instead of having the flint button of glass *cemented* into the depression ground into the distance crown glass lens they are fused together by electric heat by a patented process and are to all intent and purposes an integral lens and are justly popular and successful. When well made they are as nearly invisible and probably as nearly perfect as it is possible to produce a lens having two powers. Their surfaces are perfectly smooth. They, like the cement style, may be made of any power or combination of powers desired. Spheres, cylinders, and prisms may be combined. Both upper and lower lens may be perfectly centered. They may be made of any form desired; either peritric, periscopic or bispherical. They are so nearly invisible that there is little chance of an observer discovering that the lenses contain two powers, thus indicating that the wearer has lived beyond the meridian of life.

For years many have attempted to make a satisfactory bifocal by grinding a distance and near focus on one piece of glass, but until very lately most unsatisfactorily, as is indicated above in what has been said of the so-called "solid bifocal."

Success has finally been achieved and there is a thoroughly satisfactory lens so made by a patented process which is known as the "Vetex" or "Onepiece" bifocal.

There is also a misnamed bifocal lens on the market known as the "Perfection." This lens is much like its half brother—the split style. The lower lens, instead of being half of an oval like the split is a segment of a circle. This segment is made to fit into a circle of the same shape and dimensions ground into the upper. The split and the so-called perfection styles may only be used as inserted lenses, for they depend upon the frame to hold them together. All the other styles may be made with rims or rimless.

Bifocal lenses have come to stay; especially the "Kryptok, Vetex and Cement" styles. They represent the latest achievement in spectacle-lens manufacture. When made peritric or deep periscopic in form they may be styled the IDEAL bifocals, for such they are.

Practically every objection to bifocal lenses has been swept aside by the introduction of these latest achievements in the art of spectacle lens manufacture.

Practically every civilized person is a prospective wearer of glasses; therefore, everyone must be interested in this—the greatest step forward since spectacles were first made.

Bifocal lenses, of course, are for the old or middle aged. They are more beneficial for those who require lenses for constant use than they are for those who are simply presbyopic; yet many emmetropes who have become presbyopic will prefer to wear a full lens rather than the crescent shaped ones, or to be compelled to remove their glasses when viewing distant objects. Such patients will be greatly pleased with the new invisible bifocals made with plano upper or distance lenses and with the necessary focus for their presbyopic correction added in the lower segment on account of their being able to see at all distances without removing their glasses.

Presbyopia sets in at about the age of 44, and from that time on about $\frac{1}{4}$ of a diopter manifests itself each year. If presbyopes will begin wearing bifocal lenses when a weak lens may be used, and then increase its power as presbyopia creeps on, they will hardly ever realize that they are presbyopic. Thus, these lenses will practically keep them or their eyes young.

The price of these ideal lenses for those who require two powers is now within the reach of nearly everyone. Their advantages have only to be mentioned to be appreciated.

THE FITTING OF BIFOCAL LENSES.

Bifocal lenses have been growing more and more popular year by year, until they are now worn by hundreds of thousands, who could not be induced to abandon them. Judging from the rapidity of this growth, and from the improved methods of manufacture and of mounting them, their popularity will increase as the years go by. Some of the new styles are immensely popular at present. There are a few persons, of course, who—for one reason or another—have not been able to adjust themselves to this style of glass. The reason for their rejection is often chargeable to a badly fitted frame, but more often to lenses of faulty construction. In a few instances it is chargeable to the habit or temperament of those attempting to wear them. Nervous or irritable persons are usually the ones who reject them. Such persons will not wear them long enough to become accustomed to them. Practically every calm and deliberate person, who requires two powers, will not only be pleased with them, but will wear no others, provided they are properly constructed and correctly mounted, and that they have worn them long enough to become accustomed to them. There are many people at present wearing bifocal lenses that hardly realize that they are presbyopic.

The experience of such a one may illustrate: Mr. H. says that at the age of twenty he began wearing $+ 1.00$ spherical lenses; at thirty the power was increased to 1.50 ; at forty-four he was still able to see distinctly objects beyond 15 inches, but required a half diopter more when reading. This he had added to his distance lenses by cementing a scale of that power to them. At forty-six the power of the scale was increased to 1.00 D., and this power has been increased a half diopter at a time until now he is wearing a $+ 2.50$ scale. This increase of power has been so gradual that he has hardly noticed the changes, and having always been able to see both distant and near objects with a single pair of glasses, he has hardly realized that he has been, or is, presbyopic.

Undoubtedly this patient pursued the proper course—a course, which, if pursued by others, will produce equally good

results. As stated above, there are but two general reasons why bifocal lenses are not satisfactory: One pertaining to the manufacture of the lenses and the other to the fitting of the frame or mounting.

Regarding the lenses, we should see that the optical and the geometrical centers of the distant lenses exactly coincide, and that the P. D. of the frame or mounting is exactly right. We should also see that the optical centers of the reading lenses are no farther apart than are the centers of the pupils when the eyes are converged to the reading point. The segments that produce the extra power may and should be decentered in to the same extent that the P. D. is less when reading than it is when looking at distant objects. This necessitates recording two pupillary distances on the prescription, one for distant lenses and the other for reading lenses. Either this, or what is better, note on the prescription that the segments are to be decentered in a certain amount. The amount of decentration varies from two to five millimeters, according to the width between the pupils and the distance at which the reading matter is held.

A patient with wide P. D., who holds the paper close, will require double the amount of decentration that one would whose P. D. is narrow, and who holds his paper well away.

It should be remembered that if the frame is too wide, the lenses are actually decentered out, and if too narrow, they are decentered in. It is very essential that the optical centers of the distance lenses should lie in the same horizontal plane, and the same is true of the lower lenses. If the optical center of one lens is above the same point in the other lens, artificial hyperphoria will be produced. This causes a strain on the superior and the inferior muscles, and such a strain is hardly endurable. A decentration of a 5 D. lens of only 2 mm. will produce one prism diopter. In other words, if one such lens be decentered up 1 mm. and the other down 1 mm., one degree of artificial hyperopia would be produced.

The bridge of a spectacle carrying bifocal lenses should be a little higher than would be chosen if such lenses were not to be mounted. In other words, the lenses should drop a little lower than would ordinary lenses.

The segments should be narrow—13 to 15 mm. being wide enough, as a rule. On the other hand, the distance lenses should be as wide as the patient's face will admit.

A wide lens affords a wide field vertically and that is what is needed. Those known as short oval are, as a rule, more desirable for bifocals than are the regular oval styles; such lenses increase the field vertically.

The upper edge of the segments should be well below the lower edge of the pupil when the wearer is looking at the floor 15 feet away. If the above details are carefully followed and the lenses tilted back a little at the bottom, so that the line of vision will be at right angles to the plane of the lenses when reading, there will be little difficulty in the patient getting used to them.

This is especially true if the segments are weak. Old or infirm people who have *never worn* bifocals should not attempt to wear them.

Most of the trouble found when wearing bifocals is in going down stairs. Therefore, patients should be advised to tilt the head a little, so that they look through the upper rather than through the lower lenses when going down stairs.

To obtain the best results, bifocal lenses should be made either deep periscopic or peritoric in form, and as wide as the patient can wear. Of the various styles of these lenses, the Kryptok and Onepiece styles are undoubtedly the best. The segments of these lenses are practically invisible. The segments of the cement style, known as Opifex, are also quite invisible. The above three styles remove one great objection some people have to wearing bifocals, i. e., the segments being invisible, the lenses imply no particular age. In spite of the extra cost of the above styles, they are very popular. The ordinary style of cement bifocal lenses—if well centered and carefully mounted—will prove satisfactory.

KRYPTOK LENSES (HOW MADE).

A Kryptok lens is made by the fusing of two glasses of different indices of refraction.

The major or distance lens is made of crown glass, while the segment or reading portion is of that variety known as flint.

Crown glass is of a hard nature, and for illustration we will say has an index of refraction of 1.52. The flint is a lead glass and is considerably softer than the crown, and we will assume for illustration that its index is 1.62. Our ratio between the crown and flint is then 5 to 1. In other words, a curve that would produce 5 D if ground upon crown glass would produce 6 D if ground upon the flint variety.

Therefore, if we are thoroughly familiar with the index of the two glasses, and having the knowledge that a 5 D curve produces an addition of 1 D if ground on flint glass, it is an easy matter to proceed.

Kryptoks are first manufactured into blanks, in which form they are distributed to the jobbers.

Suppose that it is desired to produce a blank that will add 2 D to a plano. We select a piece of crown glass about 45 mm. square and 5 mm. thick and grind a countersink or — 10 D curve with its center in the center of the blank about 30 mm. from the top.

The diameter of the depression is usually about 25 mm. We also select a piece of flint glass shaped like a button, about 25 mm. in diameter and about 5 mm. thick. Upon one side of this glass we grind a convex or + curve of 10 D. The curves upon both the flint and the crown glass have practically the same radius, one being concave and the other convex, but owing to the different index, as explained above, the crown glass will have a power of only 10 D while the flint will have 12 D.

If these lenses are placed in contact the (crown glass) — lens will neutralize but 10 D of the + 12 D flint lens, leaving + 2 D, or the amount desired unneutralized.

The countersink and segment must be ground and polished with the utmost care and precision. The tools used are contin-

ually examined and are true to 1/1000 D. After each operation each glass is carefully inspected, and when the final polish is accomplished it must be absolutely perfect in order to produce a satisfactory blank. After passing all inspections as to correctness, character of surface, etc., the glass is sent to the fusing room.

Successful fusing is done under only the most favorable conditions necessary to such an operation. The absence of dirt and dust is one of the most important conditions. The single touch of a finger on the disc or countersink will make a spot in the blank, which, if not detected, will render the blank useless, and an imperfection impossible to see in the countersink or on the disc will be enlarged in the fusing to a spec sometimes as large as a pin head, making the blank absolutely worthless.

There are numerous methods of fusing, but the process we will illustrate permits one side of the flint glass to have the same curvature as the countersink, the curve of course being reversed.

After placing the segment in the countersink the lower edge of the segment is elevated just a trifle by inserting a small piece of steel between the countersink and segment. This is done to permit the air to escape from between the countersink and segment during the fusing process and thus minimize the possibility of bubbles. After putting the two glasses together in the manner mentioned they are placed in a fusing furnace (either electric or gas) and subjected to an intense heat to occasion the coalescence or fusing of the two glasses. The flint glass becomes molten and fuses at a given temperature in the neighborhood of 1,300 degrees Fahrenheit, while the crown glass would assume a similar condition at a slightly higher temperature. The moment the fusing process is completed, however, the heat is immediately shut off or gradually reduced to a lower temperature, thus preventing any disturbance to the countersink. The blank is then removed from the fusing furnace and placed in an annealing oven, where through regulating the heat the blank gradually cools and anneals. The cooling of the blank is one of the most important operations. If allowed to cool too quickly, poor annealing is the result, and

the possibility is that the blank will snap or crack at the slightest shock or change in temperature. After allowing the blank to cool from twelve to fifteen hours, it is tested for annealing, and inspected for defects, and if found perfect is ready for prescription grinding.

The particular blank which we have illustrated will, as mentioned above, produce an addition of $+ 2.00$ if plano is ground on the scale side. Likewise the addition of this blank will increase according to the ratio of 5 to 1. Therefore if a $+ 1.25$ sphere is ground on the scale side of the blank mentioned, the addition would be $+ 2.25$. A curve either spherical or cylindrical may be ground on the reverse side of the blank, while only spheres may be ground on the scale side. When concave spherical curves are ground on the scale side the addition is reduced proportionately.

A chart is provided by the manufacturers of Kryptok blanks which indicates the blank necessary to grind most any ordinary R. Where plain cylindrical Kryptoks are ordered the cylinder is always ground on the inside of the blank, and plano ground on the scale side. Spheres may be ground either on the scale or plano side, and compounds can be executed by grinding the sphere on the scale side and the cylinder on the plano.

LENTICULAR LENSES.

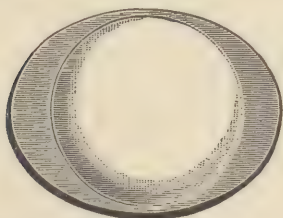
Their Form and Method of Manufacture.

The original reason for prescribing this description of lens was to reduce the weight on strong convex and concave lenses. From the time the first lens was put out, up to the present time, there have been efforts in various ways to reduce the weight and at the same time have the field of vision large enough so that the glasses could be worn comfortably.

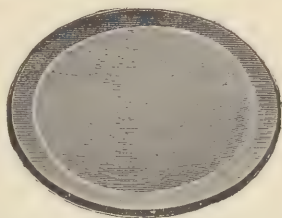
The first lenses of this description were made up in concave and convex flat form with the focus of the lens all on one side. In concave this focus was ground in the lens and the diameter of the concavity ran from 23 to 25 mm. In convex a similar size scale was used, but this was cemented in the center of a plano lens.

The next improvement was to make a larger lenticular covering, practically the full width of the lens. These are generally known as "large round lenticular." Diameter of the concavity in minus lenses may run from 28 to 30 mm. The diameter of the scale in convex will be the same. These were made on plano concave and convex.

The next change in form was to take a concave lens and strongly convex it, thereby giving outer edge of the lens not



Round Field Lenticular.



Oval Concave Lenticular Peritoric Form.

more than $1\frac{1}{2}$ mm. to 2 mm. thickness, but at the same time retaining a fairly large field of vision averaging 30 mm. This particular type of lens in double concave we consider to be about the best type of lenticular. This style is not made in convex.

In a desire to give an apparently larger field, and also to allow lens to set somewhat closer to the eye, Prof. G. A. Rog-

ers suggested that a toric lens be used as a base, and a thin knife edge scale, 28 mm., be cemented in the center, thereby decreasing the weight considerably and also allowing the lenses to be set closer to the eye.

A lens of this latter description can be made in fused bifocal form by cementing a lens to a distance base containing the proper addition for reading purposes. The toric concave of a similar description is obtained by grinding a very strong minus curve inside of a toric distance lens. This lens would be known as "toric concave" lenticular.

And lastly, an article known as "oval lenticular," ground with a weak toric base outside, generally plus 3, and with the lenticular part of oval shape, as shown in illustration on page 92.

The development in both the above lenses has been taking place in the last three of four years.

Round lenticular minus lenses may be obtained from 8 to 30 D and convex from 8 to 25 D.

Rogers round lenticular plus focus may be obtained from 6 to 22 D.

Minus lenticular toric from 6 to 14 D. Minus oval lenticular from 6 to 13 D.

A LIGHT-WEIGHT CATARACT LENS.

Prof. G. A. Rogers, of Chicago, has designed a lens that, by doing away with the heavy features of cataract lenses as made in the past will doubtless be popular when such lenses are needed. It is a form that enables the wholesale optician to fill practically any prescription calling for a high plus value, as in cataract lenses, spherical or compound, with or without bifocal features, and yet be a comparatively light lens.

The lens is a lenticular form, but the lenticular is on the concave side of a deep periscopic or toric base lens, so as to be out of the way, give the lens a graceful figure and provide the necessary correction. By the use of fused segments practically any addition for reading may be provided without disturbing the general form of the lens.

One of the valuable features of the lens, from the standpoint of the grinder is this, that he may select from regular stock suitable forms for surfacing to the demands of the prescription, whether bifocals are demanded or not. Whatever a prescription may be, the lenticular segment will have a circular outline, and the whole lens can be made on short notice.

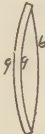
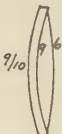
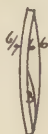
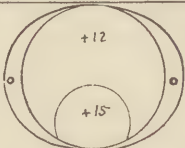
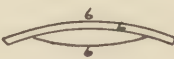
Its advantages to the oculist are equally pronounced. It avoids at once the heavy weight of a lens of the full dimensions, and the ungainly appearance of the usual form of plus lenticulars. It gains its lightness in the same way that any lenticular does; the narrow diameter allows it to be ground to a thin edge and made light but strong.

Prof. Rogers does not consider it an invention nor a discovery, exactly. Merely a happy thought in designing a lens. We believe, notwithstanding the Professor's modest estimate of it, that it might have been a long time before any one else had that "happy thought" by which the optical dispenser is able to furnish so unique a lens to his customers.

The design of the lens will be at once understood by any practical grinder from the diagrams in connection herewith. It will be seen that the design gives a marginal space for the attachment of the mountings, for the lenticular fills the vertical meridian only. For bifocals, the countersinking is on a

heavy plus curve, such as would be necessary to make the required high addition to cataract lenses.

Vertical Cross Section

<i>Distance</i>	<i>Reading</i>	<i>Fused Bifocals</i>
+12 sph.	+15 sph.	+3 sph. added
		
+12 = +1 cyl.	+15 = +1 cyl.	+3 sph. added
		
<i>Anterior-Posterior View</i>		<i>Horizontal Cross Section</i>
		

The cost of such a lens will of course vary according to the combinations desired. It will be a little more than twice that of regular lenticulars.

TILTING LENSES.

On page 543 of *Ophthalmic Myology*, Dr. G. C. Savage, the author, states that it is a well-known fact that the tilting of a spherical lens increases its refractive strength at right angles to the axis of tilting, and that the tilting of a lens to the extent of 45 degrees practically doubles its refractive power at right angles to the axis of rotation without changing its power in line with this axis. In this way a spherical lens is made to have an astigmatic effect or the effect of a spherocylinder. The above fact is easily demonstrated by anyone having access to a spherical lens.

If the tilting of a lens increases its power in one meridian, then the retinal image of an object viewed through a lens that has been tilted so that a person looks obliquely through it will be distorted, and the greater the tilt or the more obliquely the lens is looked through the more distorted the object will appear.

The above fact is easily demonstrated by holding a plus spherical lens between an electric globe and a card. The lens should be held at about its focal length from the card. A picture of the globe will appear on the card, and if the face of the card and lens are at right angles to the line of light the picture will be exactly the same shape as the globe, but if the lens be tilted so that the rays of light pass obliquely through it the picture will be elongated or distorted, and if the tilt be great the picture, instead of being the shape of the globe, will be simply a streak of light. What has taken place on the card is exactly what takes place on the retina of the eye when we look obliquely through the lens.

It is therefore an established fact that we must look practically straight through a lens if we are to obtain the best results. It then follows that a lens so constructed that the wearer can look straight through it when looking around, as when viewing a landscape, will be superior to one that does not possess this advantage.

Periscopic lenses, especially those possessing this principle to any great extent, do allow the wearer to look practically straight through them when looking in different directions.

This principle was first applied to minus lenses, which at one time were practically the only form of lenses that were worn constantly, and therefore used for all purposes. Until a few years ago it was a rare thing to see convex lenses worn except by presbyopes when reading or doing work close at hand, and for this purpose the bi-convex form, if adjusted so that the line of vision is at right angles to the plane of the lenses, is probably as good as those having the periscopic form.

The periscopic principle is recognized by opticians when mounting lenses, for they always place the side that has the least convexity next to the eye. If one side is plane and the other is convex, the plane surface is next to the eye. If the lens is plano-concave the concave side goes next to the eye. If one side is more concave than the other, that side is placed next to the eye. By thus mounting lenses the refractionist enhances their value to the wearer.

If the tilting of a lens changes its power in one meridian, it teaches us that we must use great care when placing our test lenses before the patient's eyes, for if they look obliquely through them there will be produced an artificial astigmatic error. On the other hand, a patient may be astigmatic and accept a cylindrical correction for distant vision but reject a cylinder when reading, for the tilt of the lens may exactly correct the error. In such cases the patient looks obliquely through his reading glasses, and this obliquity is sufficient to produce the required cylindrical power.

Under these conditions they would of course reject the cylinders in their reading glasses. Our test lenses then must be so adjusted that the patient looks straight through them when looking at the distant chart and also when reading. This will necessitate separate adjustments of trial frame for each test. If our test lenses were of the meniscus (deep periscopic) form they would be practically correct for both distances if properly adjusted for one position.

But test lenses of this form would be far more expensive and often inferior to those in general use. Plano convex and plano concave would also be more expensive than the bi-convex and concave forms, but they would serve the purposes for which test lenses are now used far better than the bi-convex

and concave forms do. Test lenses must be used for neutralizing purposes, and since peritric and deep periscopic lenses are now so generally used, a suitable form of lens for that purpose is needed. The plano forms are far more suitable for neutralizing meniscus and peritric lenses than are the bi-convex and concave styles, for the reason that their surfaces may be brought more nearly into contact with the surface of the lens to be neutralized. Plano forms would also be superior to the present styles for testing purposes, especially if the operator uses the fogging system, for the convex surface of the fogging lens would be placed to the front, and the concave surface of the neutralizing lens would be placed next to the eye. Thus the two plano surfaces would be together. We would then have practically a periscopic test lens or one with a convex anterior and a concave posterior surface. The plano forms would also be more suitable for neutralizing Kryptok and Opifex bifocal lenses now so popular.

PRISMATIC EFFECT PRODUCED BY DECENTERING LENSES.

A practical table in millimeters for decentering spherical lenses to obtain a given amount of prismatic effect. The table may also be used for cylinders if the base of the prism be at right angles to the axis of the cylinder. It may also be used for sphero-cylinders if the combined power of the sphere and the cylinder be counted as a sphere and the base of the prism be at right angles to the axis of the cylinder. If the base of the prism and the axis of the cylinder exactly coincide the

Sphere	0	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00
$\frac{1}{2} \Delta$	20.	10.	6.7	5.	4.	3.3		2.8	2.5	2.2	2.	1.8	1.7	1.6	1.5	1.4	1.3
1 Δ		20.	13.3	10.	8.	6.6		5.7	5.	4.4	4.	3.6	3.3	3.1	2.9	2.7	2.5
1½ Δ			20.	15.	12.	9.9		8.5	7.5	6.6	6.	5.4	5.	4.7	4.4	4.1	3.8
2 Δ				20.	16.	13.2		11.4	10.	8.8	8.	7.2	6.6	6.2	5.8	5.4	5.
2½ Δ					20.	16.5		14.2	12.5	11.	10.	9.	8.3	7.8	7.3	6.8	6.3
3 Δ						20.		17.	15.	13.2	12.	10.8	9.9	9.3	8.7	8.1	7.5
3½ Δ								20.	17.5	15.4	14.	12.6	11.6	10.9	10.2	9.5	8.8
4									20.	17.6	16.	14.4	13.2	12.4	11.6	10.8	10.
4½ Δ										20.	18.	16.2	14.9	14.	13.1	12.2	11.3
5											20.	18.	16.5	15.5	14.5	13.5	12.5
5½ Δ												20.	18.2	17.1	16.	14.9	13.8
6 Δ													20.	18.6	17.4	16.2	15.
6½ Δ														20.	18.9	17.6	16.3
7 Δ															20.	18.9	17.5
7½ Δ																20.	18.8
8 Δ																	20.

sphere only should be counted. If the base of the prism is exactly 45 degrees from the axis of the cylinder all of the sphere and one-half of the cylinder should be counted.

If the base of the prism is ten degrees from the axis of the cylinder, add to the power of the sphere 1/9 of the power of the cylinder; if thirty degrees, add 3/9; if sixty degrees, 6/9, etc. The same rule applies to simple cylinders. If the base of the prism is forty degrees from the axis of the cylinder count 4/9 of its power as a sphere; if seventy degrees, count 7/9, etc. Standard sizes of uncut lenses if cut to 0 eye

may be decentered 3 to 5 millimeters. If greater decentration is desired the manufacturer must resort to extra large lenses or surface grind them upon a prism.

TRIFOCAL LENSES.

A lens having three focuses or powers is sometimes desirable. A myope of high degree, who is also a presbyope, will find such a lens desirable, for they, as a rule, are not able to wear with comfort a lens that corrects their myopia in full, yet they often wish that they could see more distinctly than it is possible to with a lens that they can wear continuously. For instance, a patient having 16 D of myopia, as a rule, will not be able to wear continuously with comfort more than 14 D, but would tolerate for a few minutes their full correction. Such a lens is produced by cementing a narrow — 2.00 D scale to the top of their distance lenses. Such a scale made not more than 7 or 8 millimeters wide will not interfere with their vision through their 14. D as ordinarily worn, but by dropping their head a little, so as to look through the upper part of their lenses, they will have the benefit of their full correction. If such a patient be also presbyopic a narrow + scale may be cemented to the bottom of their lenses, which will correct their presbyopia.

Emmetropes and hyperopes as well as myopes will sometimes find a trifocal lens useful. For instance, a watchmaker or a dealer in precious stones may wish a lens with three different powers, one for distant seeing, another for seeing at thirteen inches and still another for seeing at three inches or less. The latter lens is for magnifying purposes or for use as a loupe.

Such a lens is produced by cementing to the upper part of the outer end of the right or left lens as desired a small + 13 D scale. When wishing to use the short focus lens the wearer tilts his head a little and is then looking through the + 13 D lens or whatever power he desires. The wearer of such a lens is able to examine anything while holding it close to his eye, thus obtaining a greatly enlarged retinal image, or, what is the same thing, a magnified image.

EYEGLASS AND SPECTACLE NOMENCLATURE.

There is much in a name, especially when by it we wish to make known our wants. Therefore, the name given should be one universally accepted as correct.

What is known to the optical world as an eyeglass has been given a great number of names. Some of them do not even suggest what is wanted. Among the names most frequently used for eyeglasses are the following:

Nose Glasses; Nose Spectacles; Nose Pinchers; Folders; Pinc Nez; Spring Glasses; Arch Glasses; Bow Spectacles, etc.

We presume that the persons using the above names supposed that they were furnishing exact information as to what they desired. There are two distinct varieties of eyeglasses: One is known as rimless, the other as a rimmed eyeglass. The metal part of the former is known as an eyeglass mounting, the lenses being held by clamps and screws, while in the latter they are held in grooved eyewires. An eyeglass frame consists of eyewires, studs, guards and spring, while an eyeglass mounting consists of clamps, studs, guards and spring. The clamps are soldered to the studs, as are the eyewires of the frame.

There are many different styles of eyeglass springs. They are known as "Hoop," "Oblong," "Tilted," "Grecian," etc. Each style is made in different lengths and in different forms, some being "reduced," some being "swelled," etc. There are also several different styles of studs, such as "Outset Strap," which hold the lenses away from the eyes, and "Inset Strap," which place the lenses in closer to the eyes than do the regular studs; the "Drop," which lowers the lenses; also those differing in length, which are known as "AA," "A," "B," "C," "D," etc. The "AA" being the shortest and "F" the longest, the interval between the different lengths being one millimeter. Of guards, there are hundreds of styles, each style being known by a name or number, or by both name and number. (For names and numbers of guards we must refer to the catalogues issued by the wholesale optical houses.)

There are now many new styles of eyeglass mountings differing from those described above, in that they have rigid

bridges like a spectacle in place of the ordinary bow spring. The guards on the rigid bridge eyeglass mountings are actuated by small spiral springs and are controlled by finger pieces extending in front of the lenses and are known as "Finger Piece Mountings." These new styles of rimless eyeglass mountings have specified names, such as "Vici," "Fits-U," "So-Easy," "Knu Digit," etc. Each style is made in several different sizes, and each size is designated by a number given it by the manufacturer.

When ordering any of these new styles of eyeglass mountings it is necessary that exact information, not only as to style, but also as to dimensions, should accompany the order. We know of no more satisfactory way to obtain dimensions which will be correct for any particular case than to have samples of known dimensions for fitting purposes.

The great popularity of rimless eyeglasses has stimulated their manufacture, and also the inventors, to produce new and improved styles. There is now upon the market a great variety of eyeglass mountings which are both practical and becoming, especially so if well fitted.

Spectacles as well as eyeglasses are often given odd names. They are made rimless and with rims; they are also made in several styles, known as riding bow, half riding bow and straight temple.

A spectacle frame consists of eyewires, end pieces, bridge and temples. A spectacle mounting consists of a bridge and end pieces having clamps to hold the lenses and temples. Spectacle temples are known as riding, half riding, turn pin, band slide and straight; of the riding style there are several varieties; they are known as comfort cable, cable, half cable, spiral spring, spiral tip, spiral shield and solid wire. There are two different styles of joints on the temples, known as regular and flat joints. Temples also have different tips: some are pear-shape, some ball tipped, and some are padded.

All styles of temples are made in different lengths. The riding variety are made 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$ and 7 inches long, the 6-inch being the regular length of both riding and straight. Extra long straight temples measure 7 inches. Of bridges there are several styles, known as C or curled; S S or saddle,

X, K, Arch, Liebold and Snake. Riding bow frames or mountings usually have saddle bridges, and straight temple frames C bridges. The ends of a saddle bridge, which are soldered to the eyewires or clamps, are known as shanks. They are made different lengths and are known as regular, long and extra long shanks. An X bridge is sometimes called a reversible bridge, as with such a bridge the spectacle can be worn either side up. Of end pieces there are four different styles, all having a name which usually indicates some peculiarity, such as extra long, or short, or Alexis, the latter being reversible.

THE FITTING OF A RIDING BOW SPECTACLE.

If a riding bow spectacle is to be satisfactory in every respect the following ten dimensions should be carefully taken and written in the formula describing them. The first four of these dimensions must always be given if a frame or mounting that will be approximately correct is to be furnished. Yet

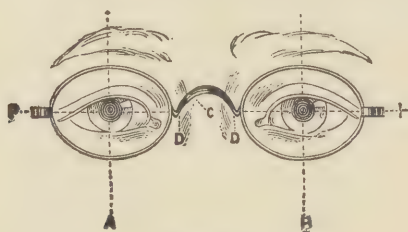


FIG. I.

every one of the ten dimensions noted below should be given careful attention, for if a single one of the ten be wrong, discomfort or dissatisfaction must result.

1. The interpupillary distance (P. D.), that is, the space between the centers of the pupils. (A, B, Figure I.)
2. The size and shape of the lenses. (Size of eye.)
3. The height of bridge measuring from the pupillary line (P P, Figure I) to the lower edge of the crest of the bridge (C, Figure I).
4. The width of the bridge at its base, that is, the dis-

tance between the lower points of the bridge where they cease to touch the nose. (D D, Figure I.)

5. The inclination, meaning the position of the *central* portion of the posterior surface of the lenses (not the edge) is distance of the upper edge of crest of the bridge, either forward or back from the central portion of the posterior plane of lenses.

6. The angle of crest, by which is meant the angle which the crest subtends to the plane of the temples, as shown in Figure II.

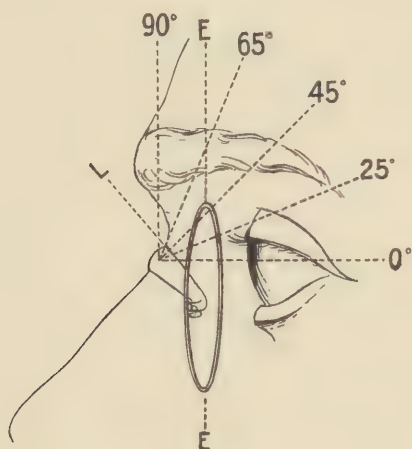


FIG. II.

7. The distance between the temples measured at a point one inch back from the joints.

8. The temple length measured from the inner surface of the joint to the back of patient's ear. (See Figure III.)

9. The total length of temples.

10. The angle of joint, by which is meant the inclination of the joint to allow the lenses to be tilted for reading or other purposes.

In taking measurements for spectacle frames or mountings, a certain system should be followed; that is, the measurements should be taken up one after another in regular order. A set of trial frames, the dimensions of which are known, will greatly assist in getting the proper dimensions.

The first and most important of the above measurements is the pupillary distance (P. D.). This is best taken with a small vest pocket rule, measuring from the inner edge of the phil of one eye to the outer edge of the pupil of the other.

If the glasses are for constant use, the patient should be looking steadily at an object some distance beyond the operator when the measurement is taken. The operator should hold the rule in his right hand, letting it rest upon the patient's nose with its upper edge just above the pupils, and one end at the inner edge of the pupil of the right eye. Then note where the outer edge of the pupil of the left eye comes (or

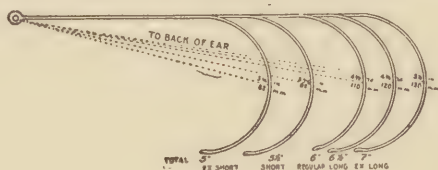


FIG. III.

the edges of the iris may be used); by this method very exact measurements can be taken, especially if the operator will close his right eye when placing the rule and his left when noting the P. D. If the glasses are for reading, or close work only, the patient should be looking at the operator's forehead or upheld finger when the measurement is taken.

The second measurement to be considered is the size and shape of the lenses (known as size of eye). When considering this, it is well to remember that the total length of one lens and the distance between the two lenses should exactly equal the P. D. For instance, if the P. D. is 63 mm. and the distance between the eye wires of a spectacle frame, the bridge of which fits the patient correctly, is 23 mm., the lenses must then be 40 mm. long. The lenses should be as large as possible, or as large as is compatible with the patient's features. This is especially true if toric, rimless or bifocal lenses are to be prescribed. Rimless should be one size larger than rimmed lenses, and toric should be one size larger than rimless or two sizes larger than rimmed. Half-eye or crescent shaped lenses are desirable for presbyopes, especially so if no lens is required for distant vision. Short oval lenses

should be prescribed if the nose is thick, or P. D. narrow. When a large lens is desired it may be provided for by bending the shanks of a saddle bridge in, as shown in Figure IV, and for each millimeter they are bent in the length of the lens should be increased two millimeters.

The third measurement to be noted is the height of the bridge. The correct height is best obtained by the aid of the trial frames noted above. The center of the lenses should be slightly below the center of the pupils when the patient is looking horizontally. A compromise between what might be considered the correct height for distant, and the correct height for near work, is what may be considered correct for glasses prescribed for constant use. Glasses used only for reading or close work should be about 2 mm. lower than those that are for constant use. Reading glasses should also be ordered slightly pantoscopic, but are not so made without special instruction.

The fourth dimension to be considered is the width of the bridge at its base. This measurement, like the third, is best obtained by the aid of trial frames with bridges of known widths. The contour of the nose and of the bridge should be the same. If it is the bridge will touch the nose at all points, thus distributing the weight of the spectacles over the nose more evenly than it would be if the base was too wide or too narrow. The lenses will also be held more rigid if the bridge fits correctly.

The fifth dimension to be noted is the position of the crest of the bridge in relation to the back plane of the lenses (known as the inclination). Trial frames aid materially in getting this measurement. The lenses should be as near the eyes as possible and not touch the lashes. If the lashes sweep the lenses when the bridge rests at the proper place on the patient's nose, the bridge shanks should be increased in length just sufficient to have them clear. Toric lenses afford about 2 mm. more space for the eyelashes than ordinary lenses do.

The sixth dimension to be noted is the angle of the crest. As a rule an angle of 45° will rest comfortably on the nose, and if no angle is noted in the prescription such a one will be furnished. A bridge having such an angle will rest comfortably

on a nose that does not vary more than 10° either way from 45° , but an angle of 10° (nearly horizontal) or one of 80° (nearly vertical) may be required.



FIG. IV.

The seventh measurement to be noted is the distance between the temples at a point approximately one inch back of the joints, or where they would nearly touch the patient's face. The trial frames again aid us in getting the correct distance.

Ordinarily the frames having the correct size of eye and length of bridge will be wide enough, and if they are this

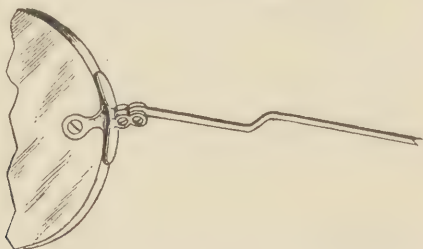


FIG. V.

distance may be omitted; but with a narrow pupillary distance and wide face, the temples would bind. In such cases they should be bent out, as shown in Fig. V, or, in extreme cases, an extra long end piece may be used.

The eighth dimension to note is the length of the temple to back of ear. The regular length of temple (6 inches), when curled, measures practically $4\frac{1}{8}$ inches from its joint end to the center of its curl. If this length is desired, this dimension may be omitted; but children often require only $3\frac{1}{2}$, or possibly $3\frac{3}{8}$ inches, while many adults require a $4\frac{1}{2}$, or possibly $5\frac{1}{8}$ inches length to back of ear. This adjustment, like others, should be correct. It can be made by curling the temples with the fingers.

The ninth dimension refers to the total length of the temples. If this length is given a temple can be supplied that can be quickly and easily adjusted, as described above.

The tenth and last notation to be made refers to the joints. This is important only when it is desired to have the lenses

tilted from the position they naturally take when the temples rest upon the patient's ears. As a rule the lenses are in the correct position when the temples are as above, but the ears may be too low. If so, the lenses will tilt out at the bottom, allowing the patient to look under them when looking down. This should be corrected by changing the angle of the joints to one that will bring the lenses to the correct position.

If the glasses are to be worn for near work only, the joints should be slightly pantoscopic, or at an angle that will allow the patient to look straight through the lenses when reading—usually an angle of 7° will be sufficient.

THE FITTING OF A SPECTACLE BRIDGE.

Practically all the art in spectacle fitting is displayed in fitting the bridge; for once the bridge is fitted, all other measurements are easily obtained. The size of eye that will be required and the length of temple to be used are both important but easily determined after the dimensions of the bridge are known.

The first point to be considered when fitting a bridge is its height, and this depends upon whether the glasses are to be worn constantly or only intermittently. If the glasses are to be worn constantly the bridge must be of such a height as will allow the wearer to look through the lenses just above their centers, when looking straight away, but if the glasses are to be used only when reading or sewing, the bridge must be higher or of such a height as will allow the wearer to look through the lenses just below their centers.

The second point to be given attention is the width of the bridge at its base. This measurement should be exactly right—no wider or narrower than is the nose at the point where the base of the bridge is to rest.

The next point to be considered is the inclination of the crest of the bridge, and this needs most careful attention, for upon it depends the position of the lenses in relation to the eye lashes; in fact, the operator may display more skill in getting this part of the bridge correct than in all other meas-

urements. If the cosmic effect is to be considered, and it always should be, this adjustment is most important.

The fourth point to be considered is the angle of the crest and this is nearly as important as the inclination, for the comfort of the patient depends largely on this adjustment; for if the crest of the bridge does not lie flat on the wearer's nose, discomfort is sure to follow. The fitting of the bridge requires not only exact measurement but good judgment as well. The dimensions of a well fitting bridge may be most easily obtained by using a set of trial frames, the dimensions of which are known. The more proficient one becomes, the fewer of these frames will be required.

The operator after carefully scrutinizing the patient's nose, eyes, eyebrows, lashes, and their face, generally should select a frame from among his samples that has a bridge that appears to be most suitable. This frame he places upon the patient and notes its appearance. If good judgment has been exercised in selecting the frame, the measurements may all be taken from its bridge, the crest of which should be placed properly; and by properly, we mean just where it should rest in order to look well and be comfortable.

The sample frame should be in perfect alignment. Its bridge must be symmetrical, temples and eye-pieces true and it must have lenses inserted. With all these things attended to before the frame is adjusted, you will be able to judge of a fit.

First, see that the bridge is of the proper height. If it be too low or too high, estimate the amount and note it on the **R**. Next, examine the width and estimate the amount, if any, that it is too wide or too narrow at its base. For various reasons it is better to select a bridge that is too narrow than one that is too wide, for the width may easily be made greater with a pair of pliers with plano, convex jaws.

It should also be remembered, the narrower the bridge is the larger the lenses may be. After the height and the width have been decided upon, the inclination should be observed, and it is here that great skill may be exercised. Often the eyes are set deep in the head, or the nose is very prominent, or the nose may be flat, and the eyes prominent, and lashes

long. If so, the inclination of the bridge used as a sample may not be correct. In the former case, the lenses will be far from the lashes and in the latter they will sweep the lashes. If the lenses are held too far from the eyes, the shanks of the bridge will have to be shorter than are those of the sample bridge. On the other hand, if the lashes touch the lenses the shanks will have to be increased in length. If the operator stands at the side of the patient and watches the lashes as the patient's eyes are slowly opened and closed, he will be able to determine very closely how much must be added to or taken from the length of the bridge shanks in order to place the lenses as close to the eyes as possible and not have them touch the lashes. When the patient looks down at a certain angle the lashes will be as near to the lenses as they ever will be. It is well that the operator see that the sample frame is on the face correctly and that the lashes of both eyes clear the lenses.

The fourth notation to be made is the angle that the crest of the bridge should have in order that it lay flat on the patient's nose. This angle, like the inclination, should be noted in the R, provided the standard angle, which is 45° , is not correct. The correct angle may be anywhere between 15° and 70° . It is an easy matter to tell if the angle of the trial bridge, which should be 45° (the standard), is correct or not. If it is not, either the upper or the lower edge of the bridge will cut the patient's nose. If 45° is too great, the lower edge will cut. On the other hand, if it is not great enough, the upper edge will cut. The angle of the crest may be changed from 45° to 55° by angling the temples down 10° . In other words, by making the spectacles pantoscopic. This will tilt the lenses back at the bottom and place them in better position for reading or close work. The angle of the bridge may be made less by angling the bridge shanks down at a point close to the eye wire. In other words, to increase the angle of the crest, angle the temple down, and to decrease the angle, angle the shanks down.

If a radical change in the crest angle must be made, it should be done with suitable pliers and by an expert frame adjuster.

To determine the size of eye that will be correct for any particular patient, measure their pupillary distance and the distance between the inner edges of the lenses, if skeleton, or the inner edges of the eye wire of a frame and subtract this distance from the pupillary distance. In other words, the total distance between the lenses, when mounted or inserted in a frame, added to the length of one lens, must equal the P. D. Example: P. D. 60 mm., distance between lenses 22 mm., length of lens (eye) 38 mm.

As a rule the sample frame should have six-inch temples. If it has, it will be an easy matter to determine whether they are one-half or one inch too long or too short for the patient.

RIDING BOW SPECTACLE BRIDGES.

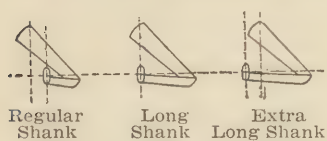
“Saddle” bridges are used almost universally now on riding bow frames and mountings. Therefore, the refractionist should thoroughly understand the system of numbering the standard sizes and shapes. They are known by letters “M”—“N”—“O” and “P.” Each of these bridges is a certain width at its base, the width of the narrowest one being fifteen millimeters (practically $\frac{5}{8}$ of an inch). It is known as “M.” The “N” is eighteen millimeters (practically $\frac{6}{8}$ of an inch), the “O” is twenty-one millimeters (practically $\frac{7}{8}$ of an inch), and the “P” is twenty-four millimeters (practically one inch).

By the above it will be seen that the interval between the different widths at base is three millimeters, or practically one-eighth of an inch. Each of them is made with three different lengths of shanks. They are known as “Regular”—“Long” and “Extra Long” shank bridges.

Each of these bridges is also made in several different heights—the interval between the heights and lengths of shank being $1\frac{1}{2}$ millimeters ($\frac{1}{8}$ of an inch). The height of the bridge is measured from the lower edge of the crest to a line bisecting the center of the joints or lenses, or from the points where the shanks are soldered onto the eyewires or clamps. A bridge, the crest of which is on line with the center of the joints, or one having no height, is designated by a letter only,

as an "M," "N," "O" or "P" bridge. An "M" bridge, the crest of which is $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ of an inch) above the center of the joint, is known as "M $\frac{1}{2}$." If the bridge is three millimeters ($\frac{1}{8}$ inch) high it is an "M1." If $4\frac{1}{2}$ millimeters ($\frac{3}{16}$ inch) high it is an "M1 $\frac{1}{2}$." If six millimeters ($\frac{1}{4}$ inch) high it is an "M2," etc. The letter always indicates the width at base, and the number the height—three millimeters being written as whole numbers, as "1," "2," or "3," and one and one-half millimeters as half numbers. Three millimeters are practically equal to one-eighth of an inch, and one and one-half millimeters to one-sixteenth of an inch.

The position of the crest of the bridge in relation to the plane of the lenses is governed by the length of the shanks. The regular length places the crest $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ inch) forward of the back plane of the lenses, a long shank places it on line with the lenses (known as "on line"), while the extra long shank places it $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ of an inch) back of the lenses. (See illustration.)



When a bridge with long or extra long shanks is desired, the letters "L. S." for "long shank," or "E.L.S." for "extra long shank" should follow the numbers. For instance, suppose a bridge eighteen millimeters wide ($\frac{6}{8}$ of an inch) at base, and six millimeters high ($\frac{1}{4}$ of an inch) with crest $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ of an inch) back of lenses is desired, the bridge number would be "N2, E.L.S." If the crest is to be on line with the back plane of the lenses the number would be "N2, L.S." If $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ of an inch) forward, simply "N2." Regular shank bridges are always furnished if no inclination is noted.

The signs "+" or "-" may be used to indicate the position of crest the "+" sign meaning "forward" and the "-" sign "back of plane." For instance, if a bridge with crest $4\frac{1}{2}$ millimeters ($\frac{3}{16}$ of an inch) back of plane is desired, it may be written "N1— $4\frac{1}{2}$," or "-" any amount desired. If the crest is to be more forward than the position would be with regular shanks, which is $1\frac{1}{2}$ millimeters ($\frac{1}{16}$ of an inch) it may be writ-

ten + 3 millimeters ($\frac{1}{8}$ of an inch) or as much + as is desired.

Measurements may be obtained more accurately if the refractionist will use the metric system and give dimensions desired in millimeters. The author advises the use of this system for all measurements for spectacles and eyeglasses.

It will readily be seen that while all "saddle" bridges are made as described above, that there are many sizes and shapes of noses that will require bridges of special bending, and different from the standard shapes in some particular. It is here that the work of the wholesaler or manufacturing optician is made easier and more exact by careful specification of the dimension wanted.

FINGER PIECE MOUNTINGS.

THEIR USE AND ADJUSTMENT.

Within the last few years there has been placed upon the market a new style of eyeglass mounting, the principles of which are radically different from those formerly in vogue. This new style almost immediately received public favor and has grown more and more popular as its utility and beauty have become known.

This mounting is fast superseding all other styles of lens mountings. It is known as a Finger Piece eyeglass and is so called because it may be removed or adjusted without touching the lenses. These mountings have many excellent features; they also have some bad ones. Among their good features may be noted a rigid bridge or one that holds the lenses in perfect horizontal and vertical alignment, or in the same position as would a riding bow spectacle with a saddle bridge.

With such an eyeglass the axis of cylindrical lenses will be held correctly, or as nearly so as they would be if mounted in a spectacle.

The guards of these mountings are of various shapes. They are made to grip the nose by small springs which force them together or against the nose. The arms of the guards are

pivoted to the bridge near the lenses; they project both forward and rearward. The forward ends are bent outward over the lens clamps and form finger pieces which may be gripped by the thumb and forefinger when the glasses are to be removed or adjusted. The guards are attached to the rearward extension of the arms. Some of them are attached rigidly and others loosely, or in such a manner as to allow them to rock. The former are known as rigid and the latter as rocking guards.

Those styles having rigid guards are susceptible of much greater adjustment than are those with rocking guards, yet both styles have both good and bad features. (We are glad to note, however, that the manufacturers of both styles are gradually eliminating the bad features.) The rearward ends of the guard arms may be bent up for the purpose of lowering the lenses, or down if it is desired to raise the lenses or to set them higher.

This makes the adjustment for height very easy and allows the lenses to be drilled at the center. The angle of the guards may be changed at will, also the spread at the top or bottom or at both top and bottom. The flare may also be quickly changed to any angle desired, so that the guards will lie flat upon a nose of any shape. As a rule the guards are made entirely of metal and are easily given any curve desired, either at their tops or bottoms, or both ends may be curved as desired.

The bridges have different lengths and different heights, also different inclinations.

The dimensions of the bridges are practically the same as are those on riding bow spectacles. When one of these mountings is correctly adjusted the bridge will rest upon and have the same contour as the nose, thus doing away with the unsightly spring of the old style eyeglass. It was almost impossible to place the old style upon the nose twice alike, for if the guards did not rest upon the identical spot each time the lenses would not occupy the same position. They might have a greater or less pupillary distance, or they might not lie in the same horizontal or vertical plane or have the same inclination or height twice.

One great fault with the old style was the drooping of the lenses. This drooping was a vital error if the lenses contained a cylindrical element, for the axis of the cylinder was surely removed from its true position if the lenses drooped.

Practically all the faulty features of the old style eyeglass have been eliminated in the new style. The bridge being rigid, the distance between the centers of the lenses is always maintained and they are always held in the same vertical and horizontal plane. The inclination may not always be exactly the same (this is not vital, however), but it is more nearly maintained in the new than in the old style. This is due to the fact that when the new style is being adjusted the bridge is made to rest upon the nose, and when the fingers are removed from the clips the guards fall upon the same parts of the nose every time. The optician, when fitting the old style, had to choose his guards from a score or more of different styles and his spring from dozens of different shapes and sizes, and his studs from many different lengths and styles, and then to assemble them and afterward to adjust them to the patient's nose. This selection of the most suitable material and the final adjustment requires not alone experience, but both experience and skill. For this reason many oculists have practically refused to prescribe eyeglasses in many cases. They could not be confident that certain lenses would prove satisfactory if mounted in an eyeglass. This fear of eyeglasses is wearing away and they are now prescribing the new style with confidence. The springs on these mountings have given the manufacturers more or less trouble, but evolution has been and is still going on and in time these new mountings will be worn almost universally except by the aged or infirm and by children. The beauty of the new style is universally admitted and there is no question, especially among the ladies, that the wearer of a modern rimless eyeglass looks many years younger than they would if they wore spectacles.

These mountings are adapted for all styles of lenses, particularly for the Peritoric styles and for bifocals.

Any P. D. may be obtained by prescribing a lens whose length plus the length of the bridge equals the pupillary distance. Short ovals and torics are popular shapes.

SHELL AND ZYLONITE FRAMES.

Shell and Zylonite frames, both eyeglass and spectacle, are worn partly because they are stylish and also because they are light weight and comfortable.

Originally they were intended for reading only, as an extra pair for use in the office or library, but as they became more popular they have been used for constant wear also, with only distance lenses.

They may be fitted in bifocal form, great care being taken to have the scales for reading in the proper position, as regards height and position horizontally before the eyes.

Peritoric lenses are recommended when ordering bifocals because with the deep concave curve they naturally tilt the lenses for reading, as it is not satisfactory to tilt temples in Shell or Zylonite because they do not fit into a case properly when bent in this manner.

The spectacles must be properly fitted, especially as regards temple width and length to back of ears, and also must be shaped to the exact contour of the back of ears. When so adjusted, should be comfortable for either use. In a few cases they are ordered for children because they do not bend or get out of alignment.

Shell and Zylonite frames are made in 38, 40, 42 and 44 mm. round and can be made in leaf shape eyes.

Shell frames are practically the same color, while Zylonite frames are made transparent, amber, mottle, brown, black and sometimes an ivory white.

Shell frames are very brittle and crack very easily, sometimes with no apparent cause, and of course the variation of positions of bridge forward and back of plane of lenses is limited. Therefore the "out of the ordinary" arrangement of bridge and pupillary distance cannot be fitted perfectly with Shell frames, unless the pupillary distance can be arranged by decentering the lenses either nasal or temporal, and by the use of Toric lenses to allow for extra long lashes.

Zylonite frames are not so brittle and stand rough usage

much better than genuine Shell. They are made in Zylonite throughout, and in this style are subject to the same limitations, as regards adjusting, as the Shell frames. They are also made with metal bridges attached to the Zylonite eyewire, and also metal end pieces, so that any adjustment of bridge and any style or length of temple may be obtained the same as the regular metal frames.

Frames that are Shell or Zylonite throughout are stronger and will wear longer, owing to the fact that the front is all one piece and contains no rivets or clamps at points where the strain is greatest, and in cases where it is possible to use them, the greatest amount of success is obtained by this style of frame.

Some patients object to the combination gold filled and Zylonite from a cosmetic point of view, while others prefer it.

The process of fitting lenses into Shell and Zylonite frames is a delicate one and can only be done accurately by skilled workmen who have had experience in this line of work. The lenses are sprung into the eyewires after heating them, either with boiling water or the use of an electric stove. The bending of temples to fit the contour of the ears is done after heating them in the same manner.

When ordering Shell or Zylonite frames, give measurements the same as for any R. B. frame.

The same general rules and description apply for Shell and Zylonite eyeglass frames as for spectacles. They are also made with metal guards which allow greater adjustment as compared with frames which are Shell or Zylonite throughout. Both are made in folding and non-folding styles, although the folding style is more liable to breakage and is more easily out of alignment. A ribbon cord and slide is considered a necessary accessory to these frames, which adds to their appearance, and also saves breakage in case of accident.

A liberal assortment of Shell or Zylonite eyeglass or spectacle frames may be obtained from your wholesale firm, on memorandum, in cases where there is a doubt whether this style frame will be satisfactory.

RECORDS

Every refractionist should keep on file a complete record of each case refracted so as to be able to refer to and duplicate lenses, frame or mounting without the necessity of later examination.

There are a number of different forms of Record Books and Record Cards to choose from and before deciding on any special system a thorough study of them should be made to find the one best adaptable for individual uses. The first Case Record system published was in book form and there are quite a number still in use but the Card system is gradually replacing these.

The chief objection to the Case Book is that the records cannot be kept in a systematic way as the average book contains only 200 or 400 record sheets, and this is a disadvantage to the busy refractionist for in order to look up a record it is necessary to know the approximate date in order to find the proper book.

The Card Record can be filed in alphabetical order and the card can be located without trouble and this system allows for any growth.

Record Cards may be procured in sizes to fit standard cabinets, namely, sizes 5 inches by 3 inches, 6 inches by 4 inches and 8 inches by 5 inches.

A Record Card should contain spaces for the following:

Number of Case.	Ophthalmoscopic Appearance.
Name.	Accommodation.
Address.	Muscular Errors.
Sex.	Abduction.
Date.	Adduction.
Occupation.	Subduction.
Symptoms.	Superduction.
Distance Correction.	Vision Before Testing.
Near Correction.	Vision After Testing.
Ophthalmometer Findings.	Size of Eye.
Retinoscope Findings.	

Pupillary Width.	Style of Mounting.
Height of Bridge.	Size of Mounting.
Position of Crest of Bridge.	Inset or Outset Straps.
Angle of Crest of Bridge.	Style of Post.
Width at Base of Bridge.	Style of Guard.
Width Between Temples.	Style of Spring.
Total Length of Temples.	Drilling of Lenses.
Angle of Joint.	Remarks.

Any special information can be filled in under heading of remarks.

This also affords a systematic way of making a complete refraction which should be done in all cases.

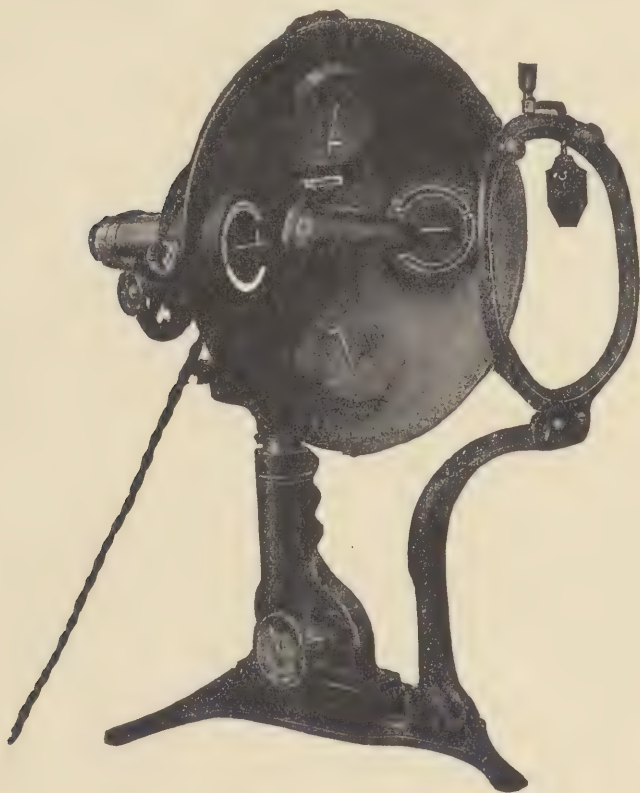
THE OPHTHALMOMETER.

The following article is the most comprehensive that has ever been written on the subject of the Ophthalmometer, and will be interesting and helpful to present users of the instrument as well as an unanswerable reason for its use to those who do not already own one of the instruments.

The writer has purposely omitted all technicalities, formulas and other matter not easily understood by even the beginner in optics, believing that the user of an Ophthalmometer wishes to know the dioptric value of a certain radius of curvature rather than the formula by which that value is obtained. The tables given are from standard works and are thoroughly accurate.

The ophthalmometer is an instrument designed to measure the radius of a curvature of a cornea, and thereby determine its refractive value. The average cornea of a normal eye has a radius of curvature of seven and eight-tenths millimeters. The refracting value of such a cornea or of a crown glass lens having such a radius of curvature is practically forty-three diopters. If the radius of curvature be shorter than the above its refracting value will be more than forty-three diopters, or if the radius be longer the refracting value will be less than forty-three diopters. If the cornea be perfectly spherical the radius of curvature, also its refracting power, will be the same

in all meridians, but if the cornea is not perfectly spherical—in other words, if it has a torodial or toric curve, there will be two principal refracting meridians, each having a certain radius of curvature and each a certain refracting value. An eye having such a cornea is said to have “regular corneal astig-



Front View.

matism.” If the cornea is curved irregularly, is wrinkled or wavy in form, the resulting astigmatism is known as “irregular.” The variety known as “regular” may be corrected with lenses, but the “irregular” variety cannot be.

The two principal refracting meridians produced by a torodial curve are practically always at right angles to each other. They are known as the principal meridians. The meridian hav-

ing the shortest radius will have the greatest power, and the one having the longest radius, the least power. The former is referred to as "the meridian of greatest" and the latter as "the meridian of least refraction," and the difference between the two as "the amount of corneal astigmatism." There is practically always a low degree of corneal error which is known as normal or "natural astigmatism." It is due to the cornea practically always having a slightly shorter radius in the vertical than it has in the horizontal meridian.

If the two principal meridians are vertical and horizontal and the vertical one has the greatest refracting power, the resulting astigmatism is said to be "with the rule." The amount of this so-called normal or natural astigmatism ranges from $\frac{1}{8}$ to $\frac{3}{4}$ of a diopter. If the corneal error be no more than the above amount, and is with the rule, it is practically always neutralized by a like amount of what is known as "lenticular astigmatism" or astigmatism due to the crystalline lens not being perfectly spherical or to other causes not clearly understood.

If the horizontal meridian has the greatest power, the astigmatism is said to be "against the rule." Such astigmatism is rarely, if ever, exactly neutralized by a like amount of lenticular error. If there is a greater amount of corneal error than is noted above, the astigmatism resulting will not be neutralized but will be real and may be exactly corrected with a cylindrical lens having the correct power, provided its axis be properly placed.

The amount of real or unneutralized corneal error may be more or less, according to the difference between the radius of curvature of the two principal refracting meridians. As stated above, the average radius of a normal cornea is 7.8 millimeters, but the radius may be as short as 6.7 or as long as 8.9 millimeters, but it is extremely rare to find one the radius of which is less than 7.0 or more than 8.5 millimeters.

The following table, copied from "Physical Optics," by Tscherning, gives the relation between the refracting value of the cornea, expressed in diopters, and the radius of curvature expressed in millimeters and hundredths of a millimeter:

Radius.	Refraction.
6.75	50 D
6.89	49 D
7.03	48 D
7.18	47 D
7.34	46 D
7.50	45 D
7.67	44 D
7.85	43 D
8.04	42 D
8.23	41 D
8.44	40 D
8.65	39 D
8.89	38 D

The principal seat of astigmatism is in the anterior surface of the cornea. It is rare to find an eye that is perfectly free from it, but when the degree is slight it has no material effect on the vision, but if there is a difference of one-fifth of a millimeter in the radius of the two principal meridians there will be more than one diopter of corneal error, and if the radius differs one millimeter there will exist six diopters of corneal error. Such an amount will very materially affect the vision. An astigmatic error must be compensated for in some manner if the vision is to approach the standard known as "normal."

As stated above, astigmatism impairs the vision, but it does not, as a rule, seriously affect the acuity of an eye unless the error remains uncorrected for a long period. It is often found that the acuity of an eye that possesses an astigmatic error of high degree surpasses the standard for normal.

As a rule the two principal refracting meridians are vertical and horizontal, but they may occupy other positions. For instance, one may be at meridian 45 and the other at meridian 135, or they may occupy any two meridians that are 90 degrees apart. If they occupy meridians other than vertical and horizontal the astigmatism is said to be oblique. One principal meridian always lies in what is known as "the vertical section," and the other in the "horizontal section" of the eye.

The section known as "vertical" extends from meridian 45 to meridian 135, and the section known as "horizontal" extends

from meridian 135 to meridian 225. If the principal meridian having the greatest refraction lies in the vertical section, the astigmatism would be classed as "with the rule," but if it lies in a meridian in the horizontal section it must be classed as being "against the rule."

When correcting a corneal error it is important that we know whether the astigmatism is "with" or "against" the rule, for if against the rule practically all the error shown by a reliable ophthalmometer will be accepted by the patient, but if it be "with the rule" a slight reduction from the amount shown is usually made. If the location of the two principal meridians is known, together with the knowledge that a certain one has the greatest refraction, it simplifies the work of the oculist very materially, for he then knows where to place the axis of the correcting cylinder, whether it be $+$ or $-$. A $+$ cylinder, if its axis lies in the meridian of greatest refraction, adds power to the meridian of least and thus equalizes the two meridians. If a $-$ cylinder be used its axis must be placed in the meridian of least refraction; it will then neutralize a part of the power in the opposite meridian, and thus equalize the two. In other words, cylinders correct an astigmatic error by adding power to a meridian that is deficient or by neutralizing power in a meridian that has too much.

One or both eyes may be astigmatic, but the amount of the error or the positions of the principal meridians may not be the same in the two eyes—one may have a myopic and the other a hyperopic error, or one may be emmetropic and the other ametropic.

If the principal meridians of both eyes lie in the same meridians, or in meridians having the same obliquity, the astigmatism is said to be symmetrical, but if they do not lie as above the astigmatism is said to be unsymmetrical. For instance, suppose the meridian of greatest refraction was at 90 in the right eye and at 70 in the left eye, or at any other meridian except 90, the astigmatism would be considered unsymmetrical, but if the meridian of greatest refraction was at 80 degrees in the left and at 100 degrees in the right eye, the astigmatism would be considered symmetrical. Each of these meridians would lie 10 degrees out from the vertical (90).

If they are an equal distance from either the vertical or the horizontal meridians, they are considered symmetrical. Those patients whose eyes are unsymmetrical—even if no astigmatism exists—experience more or less trouble with them unless the difference be so great that one eye is used to the exclusion of the other.

OPHTHALMOMETER MEASUREMENTS.

The first ophthalmometer was probably conceived by, and built for, the great Helmholtz. It was a very crude instrument when compared with modern ones, yet Helmholtz accomplished a great deal with it, for he measured the radius of curvature of hundreds of corneas and gave the results of these measurements to the world. They do not differ materially from those compiled recently. Since the original ophthalmometer was built there has been a constantly growing demand for a more perfect instrument, and this demand has been met by the manufacturers, so that the ophthalmometer of today is an instrument of great precision; it is easily understood and operated and its findings are remarkably correct.

An experienced observer with a modern instrument is able to measure the radius of a curvature to one-fortieth of a millimeter. The refracting value of such a radius is practically one-eighth of a diopter. An inexperienced observer could hardly be led astray to the extent of one-fourth of a diopter, which corresponds to almost one-twentieth of a millimeter of error for the radius. As stated above, the average radius of normal cornea is 7.8 millimeters, yet it would be an error to suppose that this radius always corresponds with emmetropia, for all eyes that have a cornea of the average radius do not measure the same through their ocular axis, some of them being too short and others too long through the above axis. The latter, of course, would be myopic and the former hyperopic. It seems that we can express the relation between the curvature and the emmetropia by saying that in the emmetropic eye there exists a constant relation between the radius of curvature of the cornea and the length of the ocular axis. If this be true the cornea of a large eye would have a longer radius of curva-

ture than 7.8 millimeters, and the cornea of a small eye a shorter radius than the above, yet both might be emmetropic. The eyes of robins and of horses may be and usually are emmetropic, yet they differ greatly in size. The refracting power of an emmetropic eye when its accommodation is at rest exactly corresponds to the length of the eye through its ocular or visual axis. The average length through the ocular axis of an adult human eye is close to 24 millimeters. We will suppose that it measures exactly 24 millimeters. Such an eye to be emmetropic must have, when in a static condition, practically 42 diopters of refracting power (to be exact $41\frac{2}{3}$ diopters).

If we compare the refracting value of the anterior and the posterior surface of the cornea of the average eye we find that the refracting power is very nearly the same as the above. The value of the former surface, according to Tscherning ("Physical Optics," page 32), is $+47.24$, and that of the latter is -4.73 , leaving the net value of these two surfaces 42.51 D, or 0.84 diopters greater than is required for an eye having a diameter through its ocular axis of 24 millimeters. An increase or a diminution of one millimeter in the length of the eye through this axis corresponds to $2\frac{1}{2}$ diopters of refraction. Variations in the length of eye through its ocular axis are greater than are variations in the curvature of the cornea, but variations in curvature affect the refraction to a much greater extent than do variations in length. A variation in the radius of one millimeter corresponds to about 6.00 D. As stated at the beginning of this article, the ophthalmometer is designed to measure the radius of the cornea and thereby determine its refracting value. The facts which we are able to determine by making these measurements are, first, whether the corneal curves are the same in all meridians or not; if they are, there is no corneal astigmatism; second, whether the radius of curvature is shorter or longer than the average; if so, how much shorter or longer; third, has the cornea a torodial curve; if so, corneal astigmatism is present; fourth, if corneal astigmatism exists, we may locate the two principal meridians and determine which of the two has the greatest power (shortest radius) and which has the least power (longest radius);

fifth, if regular corneal astigmatism is present, we can determine its exact amount; sixth, we may also determine whether the astigmatism is with or against the rule; seventh, we may determine whether irregular astigmatism is present or not and to what extent; eighth, we can determine whether both principal meridians measure more or whether both measure less than the average or whether one measures less and the other more than the average; ninth, we may determine whether the principal meridians are vertical and horizontal or oblique; tenth, we are able to determine whether the corneas of two fellow eyes are similar or dissimilar and whether the astigmatism is symmetrical or unsymmetrical; eleventh, all of the above information and more may be obtained in a few minutes and is obtained objectively, for the operator sees for himself the conditions that exist.

Taking up the first of the above claims, it is unquestionably of value to the examiner to know that an eye under examination is free, or practically so, from corneal errors, for he may then proceed with any of the other objective or subjective tests, knowing absolutely whether regular or irregular corneal astigmatism exists or not. Should the latter error be present, the ophthalmometer will disclose it at once, thus saving both the patient and the examiner a long, tedious and generally fruitless examination; fruitless because the vision of an eye, possessing such an error (even if it be of slight degree) is rarely improved with lenses. If only a low degree (one-half diopter or so) of regular corneal astigmatism is present, it may be ignored, provided it is with the rule, but if it is against the rule, it must be given consideration even if it is only one-fourth of a diopter.

Regarding the second claim, it must also be considered of value to know that the cornea of an eye has a radius of curvature, shorter or longer than the average, even if no corneal astigmatism exists, for a difference of two millimeters in the radius of a cornea corresponds to practically twelve diopters of refracting power. Therefore, should the radius be one millimeter shorter than the average, the refraction would be six diopters greater than that of a cornea having the average curvature. Such an eye as a rule is myopic.

On the other hand, should the radius be one millimeter longer than the average, the refracting power would be six diopters less than that of the average, making an eye having such a cornea most surely hyperopic. It is rare to find an eye having a cornea, the radius of which is one-half millimeter shorter than the average, that is not myopic, or to find one having a cornea, the radius of which is one-half of a millimeter longer than the average, that is not hyperopic. The above being true, the ophthalmometric measurements may indicate whether the eye under examination is myopic or hyperopic, or whether the astigmatism shown is probably myopic or hyperopic.

Regarding the third claim, ophthalmometers are designed particularly for the measurement of corneal astigmatism and their chief value in the refracting room must be considered for this purpose.

The modern instruments are admirably adapted for such a purpose, for with one of them an experienced operator will quickly determine whether the cornea is spherical or has a torodial curve. If the latter curve is present he will be able to locate the principal meridians and to measure each of them accurately, and thereby determine not only the exact amount of corneal astigmatism but also the meridian in which to place the axis of a cylinder that will correct it. He may not be able to determine whether a $+$ or a $-$ cylinder will be accepted by the patient, but he will be able to determine where to place the axis of a $+$ (if $+$ is accepted) or where to place the axis of a $-$ (if such is chosen). Once the principal meridians are located and measured, the examiner reads from one scale the meridian and from another the radius of or the dioptric value of one meridian, and from still another scale the dioptric value of the other meridian. He then knows not only where the two principal meridians lie and which has the greatest and which the least refracting power, but also the difference between them either in radius of curvature or in dioptric value.

Regarding the dioptric value of the average radius of curvature as applied to the cornea of an eye which acts like a convex mirror, there seems to be a difference of opinion.

This subject will be considered later on in this article, but this difference is practically negligible when applied to the difference between the two principal meridians or to the amount of corneal error shown. What the examiner wishes to know is, first, if there is a corneal error; second, if there is, where do the principal meridians lie; third, which of the principal meridians has the greatest power; fourth, what is the difference between these two meridians? With this information at hand, he ought to be able to form a very good opinion of the refractive conditions present in the eye.

Our fourth, fifth and sixth claims refer to locating and measuring the principal meridians and determining which of these has the greatest power. As stated at the beginning of this article, if the cornea has a torodial or toric curve, there will be two principal refracting meridians, each of which has a certain radius of curvature and, therefore, a certain refracting power. These meridians lie at right angles to each other. Of course, they must be located before they can be measured, and for this purpose the ophthalmometer is the instrument par excellence, for with it they may be quickly and accurately located; in fact, it is the only instrument yet devised for doing this particular work objectively that has any great merit. The following description of the instrument will enable the reader to understand how the meridians may be located and how measured.

When rays of light from an illuminated object impinge upon the cornea, they for the most part penetrate it, but the cornea acting like a convex mirror, reflects a part of the light so that there is a small erect virtual image of the illuminated object formed by the reflected rays.

The ophthalmometer enables us to measure the curvature of the refracting surface of the cornea by means of these reflected images. These images, of course, are very small, and therefore a high power short focus telescope is used to examine them.

Two highly illuminated targets called mires furnish the images to be examined. These mires are attached to the telescope, which is made rotary so that the mires may be brought to any meridian desired. The mires are of different shapes;

one is usually an oblong square and the other a series of steps which furnish a means of measuring the radius. The telescope usually contains two objectives, an eyepiece and a bi-refracting prism. This prism is used for the purpose of doubling the images of the mires seen through the telescope. By looking through a double prism with a single eye at a drawing like "A," Fig. 1, two of them will be seen, and if the distance between the prism and the drawing be slight, the two will be seen overlapping each other as shown at "B," or the distance between the two may be such as to cause the images to be seen just in contact as shown at "C," or the distance may be such as to cause them to be separated as shown at "D."

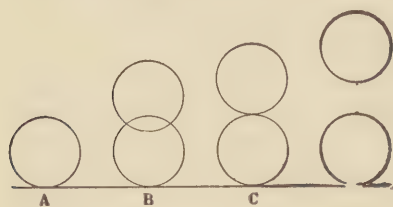


FIG. I

The mires are of a certain size, but the images of them as reflected from different corneas will vary—the shorter the radius the smaller the images will be. If the cornea is astigmatic the size of the images will

not be the same in the two principal meridians. It is by measuring the size of these images that we determine the radius of curvature of the refracting surface of the cornea, or the difference between two meridians of an astigmatic cornea. It will be seen by the above that either the mires or the prism must be adjustable in order to measure the varying images. In some of the instruments the mires are mounted on an arc and are adjustable on it. In others the prisms are adjustable in the telescope. When the mires are adjustable, the prisms are fixed in a certain position, so that their doubling or separating power always remains the same. By this arrangement the images may be approximated or brought into contact (as shown at C, Fig. 1) by moving the mires along the arc which is provided with a scale from which we read the radius of curvature and the dioptric value of that radius.

If the mires are stationary, as in the Chambers Inskip model (known as the "C. I."), the prisms are adjustable, so

that the doubling or separating power may be changed to suit the varying images.

These images may be approximated and the radius or dioptric value read from scales stamped upon the adjusting wheels. By referring to Fig. II, it will be seen that when the images are small—as when reflected from a cornea having a short radius—they must be moved farther to bring them into contact than when the images are large (as when reflected from a cornea having a long radius). In this illustration we will suppose “R” to represent the real image of one mire and “S” its secondary image; “R” and “S” move together and the same is true of “R¹” and “S¹.”

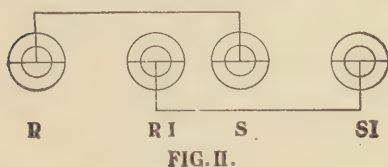


FIG. II.

If the small circles of “R” and “S” (which are the only images taken into account when measuring a cornea) are to be brought into contact, “R” and “S” must be moved farther than

they would have to be if the larger circles were to be brought together.

As stated above, the shape of the mires in use varies, but there is one feature common to all of them—they all have a straight line running through their centers. When these lines, known as meridian lines, lie in either of the principal meridians of an astigmatic cornea, they will form a straight line as shown in Fig. III, but when they lie in a meridian oblique to either of the principal meridians, they will not lie in the

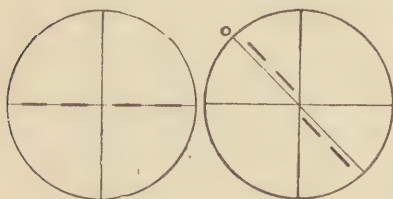


Fig III

Fig IV

same plane. The line, running through the center of one mire, will be displaced above, and the line running through the center of the other will be displaced below the central plane of the two as shown at “O,” Fig. IV. This displacement

is produced by the toric surface of the cornea.

Such a surface has practically a cylinder overlaying a sphere, and it is this cylindrical element of the cornea that the

ophthalmometer is especially designed to measure. The axis of this cylinder is found by rotating the mires through different meridians until one is found where the meridian lines lie in the same plane or are continuous. If the mires lie in a meridian oblique to the axis of the cylinder, their images are displaced toward the thin edges of the cylinder, or away from its axis—one in one direction and the other in the other direction. Therefore, they cannot lie on the same plane except as described above.

This movement of the meridian lines will be away from each other until the mires be midway between the two principal meridians. They will then approach each other and finally be in alignment again. The lateral movement of the images of the mires as they are rotated from one principal meridian to the other is always in the same direction—either toward or away from each other; toward each other when approaching the meridian of greatest refraction, and away from each other when approaching the meridian of least refraction. The mires in one style of instrument and the prisms in the other style are adjusted until their central images are seen to be just in contact. After this adjustment has been made in both meridians, the value of each and the difference between them (the amount of corneal astigmatism) may be read from the scales.

Our seventh claim refers to irregular astigmatism. Any asymmetry of this character will be detected at once, for the the images of the mires will be distorted, often so much so that they lose all resemblance to the mires themselves. The images of the meridian lines often are seen as crooked lines, and they often lie at oblique angles to each other. Errors of this character are disclosed to the examiner at once. Ophthalmometric observations are valuable in such cases because of the time saved in making the examination, and also because the reason for poor vision is made manifest. Lenses rarely afford relief in astigmatism of this character.

Regarding the eighth claim, it must be considered of value to know that a cornea has a radius of curvature shorter or longer than the average, especially if it is materially shorter

or longer, for a variation of four-tenths of a millimeter in curvature represents two diopters of refraction.

If the radius is materially shorter than the average, it indicates myopia; or if it is materially longer than the average, it indicates hyperopia.

Regarding the ninth and tenth claims, it must also be considered of value to know exactly where the principal meridians lie. This is especially true if they are oblique, or if they do not occupy symmetrical positions in the two fellow eyes. If the meridians are symmetrical, the axes of the two correcting cylinders will lie in the same plane, or will lie at equal distances from the vertical or horizontal planes of the two eyes. If the axes of the correcting cylinders do not lie in the same plane or at equal distance from the vertical, the meridians must be considered unsymmetrical.

We will suppose that the meridian of greatest refraction is at 90 degrees in the right and at 70 degrees in the left eye. Such meridians cannot be considered symmetrical, for the axes of the two correcting cylinders do not lie in the same plane or at an equal distance from the vertical or horizontal plane of the eyes. If the two meridian numbers are the same, or if the sum of the two numbers equals 180, the axes of the correcting cylinders will lie in the same plane, or will be at equal distance from the vertical plane of the eyes.

When such conditions prevail the meridians may be considered symmetrical. If the principal meridians are not symmetrical the oblique muscles are brought into play for the purpose of torting or rotating the eyes until the meridians assume symmetrical positions.

For instance, if the meridian of greatest refraction is at 90 degrees in both eyes, the patient sees vertical or horizontal lines sharply without torting the eyes, but if the meridian of greatest refraction is at 90 degrees in his right, and at 80 degrees in his left eye, he will be unable to see the same lines distinctly with both eyes. He is then inclined to tilt his head 5 degrees to the left, or to rotate his eyes 5 degrees for the purpose of bringing the two principal meridians into symmetrical positions (95 degrees and 85 degrees) so that the lines will be seen with equal distinctness by both eyes.

A blurred image upon the macula of one eye overlying a sharp image on the macula of the other eye interferes with good vision more than does slightly blurred, yet similar images upon the macula of both eyes. If the axes of the correcting cylinders are placed correctly, there will be no tilting of the head, or torting of the eyes, for the purpose of obtaining similar images upon the maculas of both of them.

It is very important, then, that the axes of both cylinders be placed correctly so that each eye may remain in its position of rest. If they are so placed, vision will be both good and comfortable. If the axes of the cylinders are not correctly placed, asymmetrical meridians may be produced. The patient then, in order to see distinctly, will rotate his eyes or tilt his head, either of which will produce more or less discomfort.

If the principal meridians are located subjectively, the patient may unconsciously, or from force of habit, tilt the head or rotate the eyes, and thereby select a meridian that is not exactly correct, or one that would not be correct if the oblique muscles were at rest or entirely relaxed.

When the principal meridians are located objectively, the patient should be looking into space with all eye muscles at rest. Under such conditions correct axes should be obtained.

Measuring corneal curvatures, for the purpose of obtaining the radius and refraction in different meridians, is known as keratometry; it is also known as ophthalmometry and as astigmatometry. The later term seems very appropriate, for the reason that such measurements are generally made for the purpose of determining the presence or absence of corneal astigmatism.

Instruments designed for measuring corneal curves are known as ophthalmometers or as keratometers, yet asymmetry of the cornea may be detected, but not measured, with a placidoscope or a keratascopic disc. A placidoscope is a circular disc on which is painted black and white concentric circles. By looking at a cornea through a central aperture in the disc a small image of it is seen reflected from the cornea. If there is no astigmatism present the image will be a small symmetrical duplicate of the disc, but if regular astigmatism is present the image of the circles, instead of being round, will be

more or less oval, according to the amount of astigmatism present. If irregular astigmatism exists the circles will appear distorted and irregular both in form and in width.

Circles have been placed upon the discs of ophthalmometers so that their images might be viewed through a telescope, but the prisms that are placed in the telescopes of all ophthalmometers double the images seen through them, and this doubling of the circles causes much confusion—therefore modern instruments do not have circles on them, but instead have a plain black disc. Such a disc serves as a screen to shut out reflections of surrounding objects, and it also furnishes a dark background for the mires.

In using an ophthalmometer a reliable source of illumination is required. Gas or electric lights placed near the mires furnish such illumination, but the best results are obtained when the mires are illuminated by incandescent lamps placed behind them.

Only the central portion of the cornea is examined, or that part forming an area extending about one and one-half millimeters in every direction from the visual line, so that the area covered by the images of the mires is usually less than the area of the pupil. For this reason it is necessary that the patient look directly into the telescope of the instrument, and that the eye be held in a fixed position. It is also necessary that the eye be wide open so that no undue pressure be exerted on the cornea by the lids, and so that the above area will be exposed for examination.

In order that the eye may be held in a fixed position and that the two eyes may lie in the same horizontal plane, a head and chin rest is provided. The chin rest is essential only as an aid in placing the eye in a position that may be conveniently reached by the telescope. An eye blind is attached to the head rest, and if the eye is in a position to be covered with this blind, and the two eyes are on a level, they will be found to be in the correct position.

The patient should be seated in a comfortable and erect position with his forehead held firmly against the head rest. He should be instructed to open the eye wide and to look steadily into the telescope, which should be raised to a level

with and directed toward the eye to be examined. The other eye should be covered with the eye cover and the mires should lie in the horizontal plane with the meridian pointer at 180.

The operator should then look through the telescope and bring it to a focus by a forward or backward movement of the telescope. This adjustment is made by rack and pinion. It is essential that a sharp image of the mires be seen. After the instrument has been focused the operator makes any slight adjustments necessary to bring the two central images of the mires into the center of the field, and also to bring to such a position as will cause the two central images to be equally distinct. If the images are not equally distinct they may be made so by raising or lowering the telescope or by moving it sideways towards the indistinct image until they are seen equally bright. When in this position four images of the mires will be in view, but the two outer ones are to be entirely ignored.

After the instrument has been focused and adjusted the telescope should be rotated through an arc of 45° , or from 180° , the starting point, to 135° . While the telescope is being rotated the operator should watch for any movement of the images of the mires. If there is no perceptible movement except the rotary one there is no corneal astigmatism. In other words, the cornea being examined is perfectly spherical. On the other hand, if the images change their position in relation to each other the cornea is not spherical but probably has a toric surface. If it has a toric surface it has two principal refracting meridians. The exact location of these two principal meridians is very important, and herein lies the chief value of the Ophthalmometer.

These meridians may be located by rotating the telescope until a meridian is found where the lines running through the centers of the mires form one continuous straight line. The meridian pointer, lying in the same plane as the mires, indicates on the protractor one of the principal meridians, and this one may now be measured. The measuring is done by moving the mires along the arc on which they are mounted until their images are approximated, or

if the instrument be one of the C. I. style, the prisms in the telescope may be adjusted until the images of the mires form a perfect cross.

The instrument is now in what is known as the primary position, and the radius of curvature, or the dioptic value of that radius, may be read from separate scales. If the instrument has two meridian indicators (and most of them do have two) the one at right angles to the meridian in which the mires lie indicates the meridian for secondary position.

The telescope should now be rotated to the secondary position and the radius again measured. This is done in the same manner as was the first. The difference between the two meridians is of course the amount of the corneal astigmatism.

One of the principal meridians is always found in the horizontal section of the eye, and this one should be located and measured first. In other words, the first or primary position should be at the principal meridian nearest to the horizontal plane. The operator will then be able to determine whether the astigmatism is with or against the rule the moment the mires have reached the secondary position. As stated above, the starting point should be at 180° . If no corneal astigmatism exists the mires will be in alignment at that point. They will also be in alignment if astigmatism is present, provided the principal meridians are horizontal and vertical, but will not be if the meridians are oblique to this plane. In either case the telescope should be rotated to the right, but not beyond the 135th meridian. If one of the principal meridians has not been located the telescope should now be rotated back or to the left until one is found. In such cases one will be found between the 180th and the 225th, which corresponds to the 45th meridian. If this rule is followed the primary position will be in the horizontal and the secondary position in the vertical section of the eye. If the radius of curvature be shorter in the secondary position than it is in the primary the astigmatism is with the rule, but if the radius be longer in the secondary than it is in the primary position the astigmatism is against the rule. It is of value to know whether it is with or against the rule

for the reason that if it is against the rule the Ophthalmometer readings may be followed closely as to the power of the cylinder on the other hand, if it is with the rule only a part of the amount shown by the instrument will be accepted by the patient provided the astigmatism is of low degree. If the error be three or more diopeters practically all of it will be accepted. This is especially true if a minus cylinder be used.

Ophthalmometric measurements are necessarily made on the surface of the cornea, but the errors shown must be corrected by lenses placed practically fifteen millimeters in front of that surface. This position practically increases the power of plus and decreases the power of minus lens. For this reason more nearly the full amount shown by the instrument will be accepted if minus cylinders rather than plus are chosen. If plus cylinders a part of the difference between what the instrument shows and what the patient accepts is made up by the position of the correcting lens in relation to the position of the images as reflected from the surface of the cornea.

It is a well-known fact that the dioptric strength of a lens, correcting the visual defect, differs more or less according to the position it is given in front of the eye. Take, for example, a case of myopia in which the far point lies 4 inches or 10 cm. in front of the cornea. This case would be corrected by a minus 10 D. lens if the latter could be worn on the cornea. But if the lens is placed at the usual position, about 15 millimeters in front of the cornea, we have to take a concave lens, the focal distance of which equals $100 - 15$ mm. = 85 mm. The lens has therefore a strength of -11.75 D. In the same way a $+10$ D. lens in contact with the cornea would have its equivalent in a $+8.7$ D. lens at 15 mm. away from the eye.

It is this circumstance which requires a change in the strength of the cylinder as compared with the amount of corneal astigmatism as revealed by the ophthalmometer. This instrument gives exactly the cylinder glass which in contact with the cornea would correct the corneal astigmatism.

If lenticular astigmatism exists to an appreciable extent it may also vitiate the readings of the ophthalmometer.

THE PERIMETER.

The importance of perimetric observations is no longer questioned.

There is scarcely a lesion of the interior of the eye which is not accompanied by perimetric symptoms. It is important, then, that a systematic series of observations by means of this instrument should be made in every case where there is evidence of deteriorating visual acuity. The Perimeter frequently assists in establishing a diagnosis, which without its use would have been doubtful. Not only this, but a prognosis of the case can often be effected by means of it that would otherwise not be possible.

A contraction of the visual field is characteristic in many of the dreadful eye diseases, or those diseases of the retina which in time produce blindness. For instance, in *glaucoma* the visual field is usually contracted, especially for colors.

In *atrophy of the optic nerve* there is always a contraction of the visual field for colors. In *advancing optic atrophy* the contraction of the visual field is usually as constant as the failure of the visual acuity. In *pigmentary retinitis* there is also a contraction of the field, and this contraction is always a marked symptom of this disease.

In *detachment of the retina* the contraction of the visual field may be measured and the progress of the disease noted. In *retro bulbar neuritis* of the acute variety there is nearly always an absolute central scotoma, but no peripheral contraction for either white or colors. Perimetric measurements in such a case must be considered paramount. In *hysteria* the visual field is often concentrically contracted, and the color field often inverted—that for red being greater than that for white.

In the varied forms of *hemianopsia* the visual field for both white and colors should be taken, for by careful perimetric measurements we may to a great extent ascertain what is taking place within the eye. The Perimeter aids in the diagnosis of all kinds of *toxic amblyopia* in that it enables the operator to discern a central scotoma for colors.

Sector shaped scotoma and *ring scotoma* together with many other forms of retinal trouble might be overlooked if the visual field were not carefully and systematically observed. We may not only ascertain the limits of the field of vision for white and for colors, but also examine its area in order to ascertain if there exists any scotoma or blind spots in the normal field, and to differentiate between relative and absolute scotoma and between subjective and objective scotoma. The limits of the field of fixation may also be measured with the Perimeter and compared with the normal fixation points, and any deficiency in the action of the extrinsic ocular muscles may be quickly discerned.

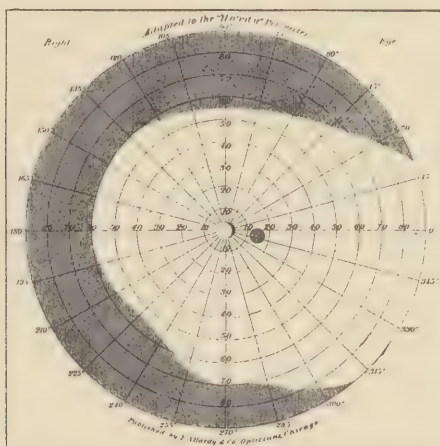
In *strabismus* the use of the Perimeter aids in tracing the fixation points and noting the degrees of deviation. With it we are also able to differentiate between *paralytic* and other forms of *squint*.

The *angle gama* may also be determined by the Perimeter. It is also useful in detecting malingerers.

When measuring the visual field which is the extent of a plane at right angles to the visual axis over which vision extends there must be a fixation point, i. e., the eye must fix upon some point situated in the plane of the eye and directly in front of it so that the image of it falls upon the macula or yellow spot. Such vision is known as *direct vision*. The object most distant from the fixation point that can be discerned will represent the limits of the visual field or the limits of *indirect vision* in that direction. All objects seen by *indirect vision* are more or less indistinct, yet this peripheral vision is of great value to us, for without it we would not be able to see anything except those objects to which the visual axis of the eye is directed. The limits of the visual field may be roughly ascertained in many ways; a simple method of ascertaining it is by means of the fingers. The observer places himself in front of the patient and about 20 inches distant from them and causes them to look at one of his eyes, which should lie in the same plane as the observed eye. If the right eye is being examined the observer's right eye and the patient's left eye should be closed or cov-

ered in such a manner as to exclude vision except in the eye being examined. The hand of the observer should be held midway between the observed and the observer's eye and approached from the outer field in all the principal meridians, or at least in the horizontal, vertical and oblique meridians.

If the observer's and the observed eye see the fingers at the same point and they are in the same plane midway between the two eyes, the fields of the two may be said to have the same extent in that meridian; but should the ob-



server discern the fingers before the observed eye does as they approach the eyes, then there is a contracted field in that meridian. A lighted taper may be used in place of the fingers. Several meridians must be tested before we are able to say that the visual field is normal. A Perimeter consists of the arc or quadrant of a circle, which in turning on a pivot at the fixation point describes a hemisphere at the center of which the eye of the patient is placed. The hemisphere thus described must be well illuminated. At the pole of the hemisphere which is opposite the eye being examined, is a white spot which the patient fixes directly. The arc is divided into degrees starting from the fixation point, which is 0, and running out to 90 degrees, the interval between the meridians being 10 degrees. The test objects consist of small

discs or squares of colored paper of from 3 to 10 millimeters in diameter. When ascertaining the limits of the visual field the observer proceeds as follows: The head being fixed in such a position that the eye to be examined is at the center of the hemisphere described by the arc of the Perimeter, the other eye being excluded from vision by being covered.

The patient is then directed to look steadily at the white spot or fixation point. The surgeon places himself behind the Perimeter where he can watch the patient's eye and note the slightest deviation from the center and also manipulate the arc and the target.

The arc of the Perimeter being placed horizontal and the target at 90° on the arc, the target is then moved toward the center or fixation point until it is just recognized by the eye being examined. This point corresponds to the limit of the visual field for that direction and meridian. The vertical and other meridians are similarly ascertained and the data noted on a chart, such as shown above. This chart represents the projection of a hemisphere upon a plane surface. This diagram shows a series of concentric circles cut by normal radii or meridian lines. The center corresponds to 0 or to the fixation point and the radiating lines to the different planes in which the arc may be placed when making the examination.

At the extremity of each radius a number shows the inclination of the corresponding meridian to the vertical. The radii are also divided into equal parts, such corresponding to 10 degrees of the divisions upon the arc of the Perimeter.

Thus, supposing the right eye to be under examination for white, and we find the limits of indirect vision in the horizontal meridian to extend to 70 degrees on the outer side and to 50 degrees on the inner side, these two points should be marked by dots on the horizontal line of the chart at points corresponding to 70 degrees and 50 degrees on the outer and inner parts respectively. The other meridians are similarly measured and marked off and the dots are finally joined by a continuous line.

A separate chart is used for each eye. If colored targets are used the connecting line should be made with a pencil

of the same color as the target used. The field for such color as a rule is different, but if the lines representing the limits of the different fields for different colors are marked as above the chart will show at a glance what they are. The colors used are fundamental, blue, red and green. In passing the test object from the periphery toward the center the blue is the first to be recognized, after that the red and next the green. Thus we find that the field for blue is almost as large as that for white, that it is larger than that for red, while the field for green is still smaller than that for red.

Other colors, like yellow, orange or violet, may be used, but the three fundamental colors named above are sufficient for practical purposes.

THE OPHTHALMOSCOPE.

Every refractionist should be conversant with the use of the ophthalmoscope and should be able to examine a fundus and to differentiate between one that is normal and one that is abnormal. This is especially true if the abnormality is due to some disease of pathological condition that, in time, may cause blindness. The refractionist should also be able to discover capacity in the humors or in the crystalline lens.

Many times it is impossible to so correct an eye with lenses that the patient will have good vision. If this is true, both the refractionist and the patient should know the reason why, and if the fundus and the interior of the eye generally has not been examined carefully, the reason for poor vision may be obscure to both the patient and the operator.

Modern Ophthalmoscopes are inexpensive, are simple to operate, and highly instructive. There seems to be no valid reason why one should not be in the possession of everyone practicing optometry.

The use of the Ophthalmoscope cannot be learned from the printed page, but must be learned by word of mouth from a competent teacher and should be a part of the knowledge possessed by every person attempting to correct defects of vision.

RETINOSCOPY.

Retinoscopy is an objective method of determining the refraction of an eye by the movement of shadows, the retina of the observed eye being illuminated by light reflected from a plane or concave mirror, the center of which is perforated to form a peep-hole through which the observer notes the movement of the retinal and facial illumination as he rotates the mirror slightly in different meridians of the observed eye.

The function of the Retinoscope is primarily to illuminate the interior of the eye that is to be refracted, and secondarily, to enable the refractionist to pick up the rays of light that emerge from the eye and neutralize them. In other words, render them parallel or bring them to a focus at a fixed point in front of the eye.

This is done by placing in front of the eye Plus or Minus lenses. The light that is reflected into the eye by means of the Retinoscope or mirror illuminates the interior of the eye, or at least a part of the retina. The rays of light that emerge from the eye are from the illuminated area of the retina. They are refracted by the refracting media as they pass through it on their way out, the same as they would be if they proceeded from an illuminated object external to the eye and were proceeding toward the retina.

If the illuminated object be at infinity or is six meters or more distant, the rays from points on it would be parallel when they entered the eye, and if the eye were emmetropic and its accommodation was at rest, the light rays would be focused on the retina. These rays will not all be absorbed by the pigments of the eye and the rays that are not absorbed will retrace their steps, as it were, and proceed back to the points from which they came, being refracted on the way back the same as they were when on their way in. They, therefore, will emerge as parallel rays.

If the eye is deficient in refracting power (hyperopic), these emergent rays will be more or less divergent according to the extent of the hyperopia present. Or if the eye has an excess of refracting power, or is myopic, the emergent rays

will be convergent. They will then come to a focus at some point in front of the eye; that point being at its punctum remotum.

When the emergent rays have been rendered parallel by placing lenses before the eye, they are said to be neutral and the lenses that neutralize these emergent rays represent the myopia or hyperopia present. If astigmatism be present, the power of the sphere that neutralizes the rays that emerge from the principal meridians represents the error present in each meridian and the difference between these spheres represents the cylinder that will correct the astigmatic error present.

This emergent light is picked up by the refractionist's eye, which must be directly back of the perforation in the mirror; therefore in the path of the emergent rays. These emergent rays illuminate the pupil more or less according as to whether they are parallel, divergent or convergent. The greatest illumination being when they are practically parallel.

The greater the error, the less bright will be the pupil, or if astigmatism is present, the meridian of least error will be the brightest. If the astigmatic error be considerable, the bright area of the pupil will be like a band of light stretching across the pupil in the meridian of least error.

The patient should be supplied with a Trial Frame into which the Trial Lenses are placed, these lenses either bring the emergent light rays to a focus at a point in front of the eye or render them parallel; the object being to bring them to a focus at the observer's eye, which should be approximately a meter distant.

If the observer be exactly a meter from the observed eye, the emergent rays will be divergent to the extent of one Diopter and one Diopter will be required to parallel them. The observer knows by the action of the light and shadows as he rotates the mirror slightly in the different meridians of the eye when the emergent light has been paralleled or brought to a focus at his eye; for the movement of the shadows will then cease or will have been reversed and the object of the refractionist will have been accomplished.

Good vision on the part of the observer is essential; also a careful and studious effort to note the movement at the central portion of a patient's pupil.

It is a good plan for the observer to be at a known distance from the observed eye so that the paralleling lenses may exactly equal this distance; for instance, if the observer is at a distance of a meter, the above lens would be Plus 1 D.; at a half meter, Plus 2; if at 2 meters, Plus .050, etc. The power of these paralleling lenses, if Plus, must be subtracted from the R in hyperopia and added in myopia.

If the observer is at a distance of a meter and always has a Plus 1. D. sphere before the eye being examined, he may prescribe the lenses, founded in the Trial Frame, after having found the point of reversal regardless of the Plus 1 sphere, which may be regarded as a paralleling lens only.

Positive information is obtained as to whether the eye under examination is hyperopic or myopic except in cases where the degrees of error are slight or when the accommodation is put in force or when it acts spasmodically.

In such cases the character of the error is uncertain. This being true, the action of the ciliary muscle must be controlled, either by a cycloplegic, or by what is known as the fogging method.

The observer should wear his correcting lenses and have practically normal visual acuity. He may use his accommodation or not as he pleases, for this does not affect the result. The test should be made in a dark room—the darker the better—and if the patient has been seated in the dark room for a few minutes preceding the examination, his pupils will have become somewhat dilated. This will facilitate the work of the examiner. The light should be bright and screened by an asbestos chimney, having an iris diaphragm. This will prevent the light from illuminating the room and will enable the operator to control the quantity of light.

The light should be mounted on an adjustable bracket so that it may be placed in the desired position.

There should be no source of light except the pencil that proceeds from the opening in the diaphragm of the chimney. The pencil of light should strike the mirror and be reflected

into the observed eye. The observer holds the mirror in front of his right eye with the peep-hole directly before his pupil and in such a position that the reflected light illuminates the pupil and also a part of the patient's face. There will then be a facial and a retinal illumination.

The rays of light that come from the patient's eye are not affected by the distance that the mirror is from the light.

The reflected light will illuminate a portion of the patient's face. The mirror is then rotated slightly from right to left, on its vertical or other axes. This causes the light to move across the pupil and across the patient's face. It also causes an apparent shadow to move across the illuminated pupil. This light always moves in the same direction as does the mirror, but the shadow does not. This may move with or against the movement of the mirror.

The object of the observer is to locate the point at which the movement of the shadow reverses. This is called the point of reversal.

It is these movements of the shadow that enable the observer to determine the character and extent of the refractive error. The shadow is the non-illuminated portion of the retina which surrounds the illuminated area. The illuminated area changes its position when the mirror is rotated; so does the shadow, but these movements may not be in the same direction, or they may be. The mirror may be rotated through the various meridians of the observed eye and the movements of the light area, and the shadows noted. The observer makes a note of these movements, their form, their direction and their speed, all of which indicate something regarding the refraction of the observed eye. The observer watches these movements through the apex of the patient's cornea, for this portion of the refracting media of the eye is what the patient uses.

There are two methods of refracting by the aid of a mirror, known as the Retinoscope. One is called the static method, and the other the dynamic.

In the static method the observer takes a position one meter in front of the patient, and with the Retinoscope mirror reflects the light from an electric bulb or a gas jet into the observed eye.

The light should be on a level with and a little to the right or left of the patient's head, and far enough back to prevent any direct rays from falling upon the cornea, or entering the observed eye.

The patient must not look directly at the mirror, but should look slightly inward, and at a specified distant object, provided no mydriatic has been used, for when looking at the mirror, the light falls upon the macula and this may cause a contraction of the pupil and a corresponding contraction of the ciliary muscle, which, of course, brings the accommodation into play.

With the Plane Mirror.

With the Plane Mirror, the apparent movement of the retinal illumination will be with the movement of the mirror as long as the observer is within the point of reversal, but as soon as the observer is beyond the point of reversal, the retinal illumination will appear to move in the opposite direction, or opposite to the movement of the mirror and opposite to the movement of the facial illumination or opposite to the movement of the light on the patient's face.

The retinal illumination will appear to move slowly if the refractive error be of great amount; but if it be of small amount, it will appear to move rapidly. It will also appear brighter as the error is neutralized by placing correction lenses in front of the eye.

When with the Plane Mirror the retinal illumination appears to move in the same direction as the facial illumination, or in the same direction as the mirror, the observer is within the point of reversal. Therefore, plus lenses must be placed before the observed eye and the power increased until all apparent motion is stopped.

If the retinal illumination appears to move in the opposite direction to the movement of the mirror, the observer is beyond the point of reversal, and minus lenses must be placed before the eye until all motion is stopped. If the eye under examination be emmetropic, with its accommodation at rest, the emergent rays will be parallel.

If the observer be one meter distant and a plus one sphere stops all motion, the eye is emmetropic; but if it takes a plus 2.00 D. to stop all motion, the eye is 1.00 D. hyperopic.

If the eye be myopic, the emergent rays will be convergent and they will come to a focus somewhere inside of infinity.

If the focal point is at a meter from the observed eye and the observer be a meter distant, the point of reversal, or the point where no motion could be seen would be at the observer's eye. In such a case the error would be minus 1.00.

If astigmatism exists, the observer must place a lens before the eye that stops all motion in the meridian of the least error and make a note of its power and then find another lens that stops all motion in the meridian of the greatest error and the difference between these two lenses represents the amount of the astigmatic error or the power of a cylinder that will correct it.

With the Concave Mirror.

The Plane Mirror is now used almost universally, but the refractionist should know how to use the Concave Mirror as well.

With the Concave Mirror the movements of the shadow are exactly opposite to those described above with the Plane Mirror.

When using a Concave Mirror, as soon as the observer ascertains the direction of the movement of the shadow, he proceeds to place plus lenses in the trial frame, beginning with plus 1.00 if the movement is against the movement of the mirror, or with a minus 1.00 if the movement of the shadow is with the mirror. He then increases the power of these lenses, 1.00 D. at a time, until the shadow vanishes. He then tries plus or minus 0.25. If one of these low power lenses of the same sign as the one in the trial frame causes the shadow to reverse, the previous lens in the trial frame is the correct one. This is true, no matter whether the mirror be plane or concave.

If the shadow movement be reversed with a plus 1.00 D., the patient is probably emmetropic or myopic to a low degree—say 0.25 or 0.50. If the shadow movement is reversed with a minus 1.00 D., the patient requires about minus 2.00 D.

The rule is, therefore, take a position one meter from the patient's eye; note the weakest lens that gives a certain shadow movement and the weakest of the opposite sign that gives a reverse shadow movement and try it out at the trial case.

Measuring ametropia by the aid of a Retinoscope is an art that may be acquired only by experience, but once acquired, is of great value, especially when measuring the refraction of children's eyes and the eyes of others having great errors.

After an observer has worked out a few cases of simple hyperopia and myopia successfully, he will be able to diagnose and correct compound errors as well. The chief difficulty will be found in locating the principal meridians, and in rotating the mirror, exactly in these meridians.

When all the conditions under which the work is done are favorable, fairly good results may be obtained by an operator who has had a little experience. The conditions are: A dark room, a medium large pupil, patient looking steadily at a distant object, accommodation suspended, a good light properly mounted and screened, a good mirror, and some experience.

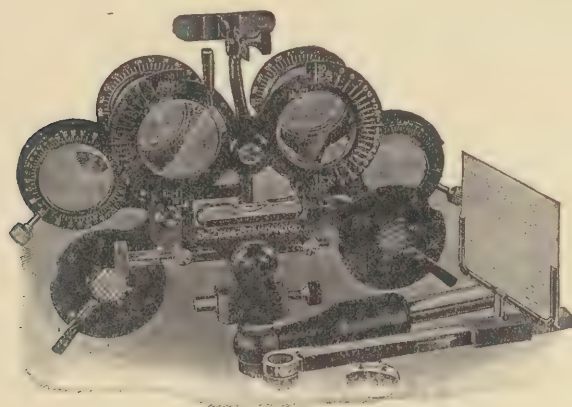
Retinoscopes are now obtainable with a battery concealed in the handle, which lights a small tungsten bulb placed just below the mirror, giving the best obtainable light for the desired purpose and the electric lighted Retinoscope is recommended as being the most satisfactory.

THE PHORO-OPTOMETER.

The Binocular Muscle Test.

[The following article, written and copyrighted by Henry L. DeZeng, is most interesting, not only as instruction for the use of the DeZeng Phoro-Optometer, but as indicating the possibilities of testing with this instrument, and will be welcomed by those who already possess this instrument, and will call the attention of others to its great value as a testing device.]

Adjust the instrument to the required position, including the brow rest and the pupillary slide, also note the spirit level



THE DE ZENG PHORO-OPTOMETER

and adjust to absolute horizontal balance. Employ the distance test types customarily used with the trial case and see that they are in direct vertical and horizontal alignment; also that they are well illuminated.

Place the required lenses from the trial case in their respective positions, the spherical numbers in the rear cells and the cylinder numbers in the front revolving cells.

When employing the complete Phoro-Optometer having the spherical lens attachment, only the front or revolving cells

for holding cylinders from the test case are provided. When the final correction for the Ametropia is found, leave it in place and proceed with the muscle test as follows:

Darken the room and employ a small, brilliant point of light, located 5 or 6 meters distant and in the same plane with the instrument. Bring both the Maddox Rod and the Stephens Phorometer into operative positions, setting each of them to Red Zero. The distant point of light and a horizontal red streak will now be seen. If the streak cuts the light there is no manifest Hyperphoria, but should it appear above the light, Right Hyperphoria is indicated, while if below, Left Hyperphoria, and in either event the Phorometer must be adjusted to such position as will cause the streak to cut the light. The graduated Red Scale on the Phorometer will indicate the character and approximate degree of Hyperphoria, "R. H." indicating Right Hyperphoria, and "L. H." Left Hyperphoria. While testing for Hyperphoria employ the Red Scale only.

Next set the Maddox Rod and Phorometer each at White Zero and begin the test for lateral deviations. The red streak will now be seen in the vertical plane, and should it cut the light there is no lateral imbalance. If the streak appears to the left of the light there is manifest Esophoria, but should it appear to the right of the light, Exophoria is manifested, and in either case the Phorometer must be adjusted accordingly, the graduations upon the White Scale indicating the character and approximate amount of the manifest error, "E. S." characterizing Esophoria, and "E. X." Exophoria. In testing for Esophoria and Exophoria employ the White Scale only.

The Double Rotary Prisms of 30 diopters with which the DeZeng Optometers and Phorometers are equipped are those known as the Crete or Risley Prisms, and are composed of two 15 diopter prisms mounted back to back, each in a separate cell. The outer periphery of each of these cells is provided with teeth which engage a pinion located between them. When the pinion is turned the prisms rotate simultaneously at exactly the same rate of speed, but in opposite directions. When the prism bases are diametrically opposed, as at zero,

the system is neutral and has no prismatic value; but when the bases are at an angle with one another, prism power exists and the base of the resultant prism equivalent is always located midway upon the arc of their approach. This would be at the 30 diopter graduation. The more acute the angle formed between the prism bases, the greater the resultant prism value will be, as indicated by the diopter scale marked upon the front of the prism case. For example: With zero vertical, and the pinion necessarily horizontal, a rotation outward to 12 upon the scale would create a prism value equivalent to 12 prism diopters, base out, while a rotation inward from zero to 12 would create a 12 diopter prism equivalent, base in. Should zero be horizontal, a rotation upward to 4 would produce the equivalent of a 4 diopter prism, base up, while a rotation down to 4 would create a 4 diopter prism, base down. Any rotation up, down, in or out, from either zero, will create a corresponding prism equivalent with base located respectively.

Do not employ the Double Rotary Prism in these tests unless the error to be measured exceeds the 10 degree range of the Phorometer. If, however, a Double Rotary Prism should be required to supplement the Phorometer, supposing the case to be one of Esophoria, bring the prism into operative position with pinion horizontal and zero graduation vertical. Set it to 10 degrees upon its outer scale and return to zero upon the White Scale of the Phorometer. The Double Rotary Prism will now add 10 degrees to the reading of the Phorometer. Should the case be one of Exophoria, set the Double Rotary Prism to 10 degrees on the opposite side of zero, which will be on the inner scale, and return the Phorometer to White Zero as before. Should the Rotary Prism ever be required to supplement the Phorometer in Hyperphoria, employ it with pinion vertical and zero graduations horizontal.

For the Duction and Cyclophoric Tests, and for Muscle Exercise, the Photo-Optometer should be provided with a Double Rotary Prism and a Maddox Rod on each side, for only when thus equipped is the instrument scientifically complete for muscle work.

The Monocular Muscle Test with Double Rotary or Mobile Prism.

While a muscle test made with the Stephens Phorometer and Maddox Rod, as already described, will usually indicate the nature and amount of an existing vertical or horizontal imbalance, such a test will not, owing to its binocular character, enable the operator to determine which eye is deviating. As an imbalance may lie in the faulty muscular poise of one eye only, a monocular duction test should be made in order to determine which muscle or muscles of either or both eyes are involved. An individual test of each of the two horizontal recti muscles of either eye may be readily made by the use of the two pair of double rotary prisms, with which every complete DeZeng Phoro-Optometer is equipped, as follows:

Remove the Stephens Phorometer and Maddox Rod from operative position, and discontinue the far point of light used in the first or binocular test, leaving in place the correction for any errors of refraction which may be present. Direct the observer's attention to a large and plainly visible letter on the distant test card, which should be located at the intersection of the vertical and horizontal median planes of the head. Now bring the double rotary prism on the right side of the instrument and before the right eye of the observer up into the operative position well against its stop, and see that the indicator or line marked upon the prism base, and also on the prism cell, registers zero upon the scale, also that the instrument is level.

To test the Adduction or contractility of the internal rectus muscle of this right eye, prism power, with base out, or toward the temporal side, should be employed.

The double rotary prism will therefore be positioned before the eye with zero vertical and the radiating pinion horizontal while in contact with the lower stop. Now turn the pinion slowly while the indicator rotates outward from zero to such position as will cause the object to appear doubled in the horizontal plane. Note the reading upon the prism scale at the point in the rotation at which diplopia occurs. Repeat this test several times, always striving for the highest prism power

which can be obtained without accompanying diplopia. The prism equivalent thus obtained will indicate the Right Adduction and should be so recorded.

To determine the Abduction or contractility of the external rectus muscle of the same eye, employ prism power base in or toward the nasal side.

The double rotary prism will therefore remain in the same relative position as before, with zero vertical, but the pinion will be turned in the reverse direction, or so that the indicator will be caused to rotate inward from zero. This inward rotation should continue until horizontal diplopia occurs. Like the former, this test should be repeated several times or until the highest prism power which the eye will overcome under these conditions is obtained. This will indicate the Right Abduction and should be so recorded.

The adduction and abduction are rated normally at about 3 to 1, or 24 to 8, being 24 prism units for the former and 8 for the latter. This, however, may vary considerably in different cases, but the rule usually applies.

To test the Superduction or independent contractile power of the Superior Rectus muscle of this eye, prism power base down should be employed. The rotary prism will therefore be positioned with zero horizontal and pinion vertical while in contact with the upper stop.

Turn the pinion slowly while the indicator rotates downward from zero and proceed with care, as the excursion will be comparatively short. The highest prism power which the eye can accept under these conditions before vertical diplopia ensues, will indicate the Right Superduction and should be so recorded.

This will usually equal about 2 or 3 prism units, but may fall as low as zero or run as high as 4 or 5 in some instances. This test should be repeated several times before a final result is recorded.

To determine the Subduction or independent contractile power of the Inferior Rectus muscle of this same eye, prism power base up should be employed and the rotary prism will therefore remain in the same relative position as before, with zero horizontal and pinion vertical. Turn the pinion slowly

in the reverse direction while the indicator is rotated upward from zero. This test, like the former, is also sensitive and must be carefully conducted if an accurate estimate of the highest prism power which can be placed before the eye under these conditions without attendant vertical diplopia is to be obtained. The strongest prism unit thus obtained will indicate the Right Subduction and should be so recorded. This will usually equal about 2 or 3 prism units, but may likewise fall as low as zero or run as high as 4 or 5 in some instances. This test should also be repeated several times before a final conclusion is arrived at.

Imbalance of the Oblique muscles, giving rise to Cyclophoria, are detected by the use of the Red and White Maddox Rods, with which every complete DeZeng Phoro-Optometer is equipped, and a distant point of light.

After completing a test of each muscle of each pair of recti muscles of the right eye, as suggested, swing the rotary prism entirely out of place and bring the one on the opposite or left side of the instrument up into operative position and proceed with the test of the four recti muscles of the left eye, the same as with the right.

When the test of each eye has been made as suggested, a comparison of the results obtained should indicate the tendency of the visual axes, and in the case of an imbalance, which muscles should receive attention. Muscle exercise, prism lenses or operative procedure may then be prescribed as desired.

For example: A binocular muscle test made with a Stephens Phorometer, Maddox Rod and distant point of light, might quickly indicate 6 prism units of exophoria, and while this would doubtless be the correct character and approximate amount of the manifest imbalance, no information would be forthcoming as to which of the four lateral recti muscles were causing the disturbance.

To determine this important question, the monocular duction test would doubtless be resorted to, and in this particular instance might show, for example, the following muscle findings: Right Adduction of 30 and abduction of 10, with Left

Adduction of 24 and abduction of 10. A comparison of these figures would plainly indicate an Exophoria of 6, with a weak left internus.

Likewise, in cases of Esophoria, Hyperphoria and Cataphoria, definite muscle measurements, made in this manner, should plainly indicate which muscle or muscles require attention.

Disturbance of the intraocular balance should be investigated by testing the extrinsic muscles of each eye separately, the same as in refraction, as the logical cause of a phoria can best be determined by a relative comparison of the monocular muscle values.

Muscle Exercise with the Mobile Prism

The exercise of a subnormal rectus muscle for the correction of either a vertical or horizontal imbalance, is effected in a most satisfactory manner through the employment of the double rotary or mobile prism, as follows:

Should the monocular duction test, in a case of exophoria, show a right adduction of 24 prism diopters with an abduction of 8, and a left adduction of 18, with an abduction of 8, the imbalance would be manifestly attributable to the inherent weakness of the left internus.

To exercise the left internal rectus, a double rotary prism should be positioned before the left eye with zero vertical, and the attention of the observer directed to a clearly visible letter located upon the distant test card, at the intersection of the vertical and horizontal median planes of the head.

An alternately increasing and decreasing prism power should now be applied with base located opposite to the muscle to be exercised and, therefore, in this instance the pinion will be turned so as to cause an outward rotation from zero to 10 or 12 upon the prism scale, and then be reversed to zero again. This alternate rotation out and back will cause the internal rectus muscle to contract steadily as the prism power increases, and then in turn relax as the prism power decreases, thereby producing a natural and effective exercise, which, as will be seen, may be applied independently to any one of the lateral or vertical recti muscles of either eye.

After exercising a muscle three or four minutes a day for several days, the working range, or maximum prism power originally employed should be somewhat increased, if the duction range has been extended by the exercise.

The maximum prism power employed in giving muscle exercise should always be less than that which will produce diplopia. If, after a few periods of exercise, the muscle shows improvement, the treatment may be continued until balance is obtained; otherwise it should be abandoned, as all cases of imbalance are not correctible by any form of muscle exercise.

DUCTION POWER OF OCULAR MUSCLES.

Adduction is the power to turn the eyes inward or to overcome prisms bases outward.

Abduction is the power to turn the eyes outward or to overcome prisms bases inward.

Sursumduction is the power of the eyes to fuse two images when one eye has a prism base up or base down before it.

Cycloduction is the verting or torting power of the oblique muscles.

Adduction.—To measure Adduction the patient should be seated six meters from a small steady light, which should be below the level of their eyes. They should be armed with a Trial Frame, into which trial prisms may be placed, bases outward, either before one or both eyes. The strongest prism or prisms thus placed before the eyes which will permit the patient to see a single light, represents the power of the eyes to turn inward, or the power of the internal recti muscles. This is called "Adduction" and is abbreviated "Add."

Abduction.—Abduction is measured in the same manner as adduction, except that the base of the testing prism or prisms is placed inward. The strongest prisms, bases inward, which will permit the patient to see a single light, represents the power of the eyes to turn outward, or the power of the external recti muscles. This is called "Abduction" and is abbreviated "Abd."

It is generally conceded that adduction should be about

three times that of abduction. For instance, if the abducting power be 6Δ (centrads) the adduction should be 18Δ , or if abduction be 8Δ adduction should be 24Δ , or if abduction be but 4Δ , then adduction should be 12Δ , etc.

Sursumduction.—Sursumduction is measured in much the same manner as adduction or abduction, except that the base of the prism is placed up or down before one eye, or if two prisms are used, one before each eye, one base must be up and the other down.

The strongest prism or prisms so placed that the eyes can overcome, or the strongest ones through which they can maintain for a short time a single image of the test light, represents the sursumduction. The power of the superior and the inferior rectus muscles are or should be practically the same. In other words these antagonistic muscles should have practically the same power.

The power of the depressing muscles (the superior recti) is known as "Supraduction," and the power of the elevating muscles (the inferior recti) is known as "Infraduction."

THE RISLEY ROTATING PRISM.

The Risley Prism is a very convenient instrument for measuring duction power. These prisms are composed of two 15 diopter prisms mounted back to back, each in a separate cell. The outer periphery of each of these cells is provided with teeth which engage a pinion located between them. When the pinion is turned the prisms rotate simultaneously at exactly the same rate of speed, but in opposite directions. When the prism bases are diametrically opposed, as at zero, the system is neutral and has no prismatic value, but, when the bases are at an angle with one another, prism power exists and the base of the resultant prism equivalent is always located midway upon the arc of their approach. This would be at the 30 diopter graduation. The more acute the angle formed between the prism bases, the greater the resultant prism value will be, as indicated by the dioptric scale marked upon the front of the prism case. For example: With zero vertical, and the

pinion necessarily horizontal, a rotation outward to 12 upon the scale would create a prism value equivalent to 12 prism diopters, base out, while a rotation inward from zero to 12 would create a 12 diopter prism equivalent, base in. Should zero be horizontal, a rotation upward to 4 would produce the equivalent of a 4 diopter prism, base up, while a rotation down to 4 would create a 4 diopter prism, base down. Any rotation up, down, in or out, from zero, will create a corresponding prism equivalent with base located respectively.

In this manner any prism power from 0 to 30Δ may be produced and by using two of these (one before each eye), 60Δ may be produced.

PRISM EXERCISES.

Duction power, especially adduction and abduction, may often be increased by a series of exercises with weak prisms. In exercises of this character the weaker of two antagonistic muscles or pair of muscles is made to do a little extra work; this extra labor being forced upon them by placing the base of weak prisms over the stronger of two antagonistic muscles or in the opposite direction to that of a testing or measuring prism.

Exercising muscles for the purpose of strengthening them or for creating an orthophoric condition, is at present far more popular than prescribing prisms for constant wear; for when prisms are worn continuously the muscle or muscles which they relieve become less and less able to perform their natural functions. This being true, the power of the correcting prism or prisms must necessarily be increased from time to time. When this is done the prismatic power finally is so great that the wearer is quite helpless without their glasses. The wearing of a prism which corrects a part of any hyperphoria that actually exists may possibly be recommended, but the prescribing of prisms for constant wear, except as above, or for the purpose of relieving the strain of convergence when using the eyes at the near point, should be left to one who specializes in that particular line. Adduction may be developed by a simple and convenient method recommended by

Dr. Thorrington in his great work on "Refraction and How to Refract." His method is as follows:

Have the patient fix the point of a pencil held at arm's length, and then slowly draw toward the bridge of his nose. As soon as diplopia results the pencil should be removed to the original distance and the operation repeated. The Doctor states that this exercise should be practiced for five or ten minutes after meals, never before, for some patients become nauseated if their stomach is empty.

This method of developing adduction is probably the most convenient and practical method yet recommended. It is certainly simple and inexpensive, for no apparatus of any kind except a pencil is required. In fact a finger nail may be used in place of the pencil point. The only thing really required is perseverance on the part of the patient.

THE CROSS CYLINDER AS A TESTING DEVICE.

The cross cylinder method of sight testing is becoming quite popular, so much so that a cross cylinder or two is now conceded by many operators to be a necessary adjunct of the trial case, and many operators use three of them. The cylindrical powers of those most commonly used are 0.25, 0.50 and 1.00 D. The latter lens, of course, consists of a $+ 0.50$ cylinder combined with a $- 0.50$ cylinder, with their axes at right angles to each other. The 0.50 power is a combination of two 0.25 cylinders of opposite character and axis, and the 0.25 power is a combination of two 0.12 cylinders of opposite character and axis. The 0.25 power is principally used as a finishing lens. These lenses are not necessarily cross cylinders, but may be, and usually are, sphero-cylinders.

The 1.00 D power being a $+ 0.50$ sphere combined with a $- 1.00$ cylinder, or a $- 0.50$ sphere combined with a $+ 1.00$ cylinder. These lenses are mounted in rims to which is attached a short round handle, which may be rolled between the thumb and index finger for the purpose of alternately placing the $+$ power in first one principal meridian and then in the other. See illustration on the following page.

The axis of the $+$ cylinder is marked in white and the axis

of the — in red. This is plainly done, and the handle is placed at an angle of 45 degrees from the principal meridians.

In order to understand the method of using these test lenses we should understand the effect of placing a lens having + power in one meridian and — power in the other meridian before an eye. If such a lens be placed in front of an emme-



tropic eye, or one that has been made emmetropic by placing correcting lenses before it, the effect is to produce an artificial

mixed astigmatism. One meridian will then be myopic and the other hyperopic, for the + cylinder will add refracting power to one meridian while the — cylinder will neutralize power in the other meridian. One effect of such a lens is to control the accommodation, or to at least hold it in check, because if it favors the horizontal meridian it will blur the vertical, or if it adjusts itself for the vertical it will blur the horizontal meridian. Hence theoretically it is kept from either exerting itself or relaxing too much.

If the lens be a + 0.50 cylinder axis 180, combined with a — 0.50 cylinder axis 90, a half diopter of power will be added to the vertical meridian, and at the same time a half diopter of the power in the horizontal meridian will be neutralized. With such a lens before an emmetropic eye the patient will see both the vertical and the horizontal lines of an astigmatic chart equally distinct, the oblique lines will be blurred. When such conditions prevail we know that the eye can focus the chart perfectly.

If a lens of the above character be placed before an eye free from astigmatism, and the lines of the astigmatic chart lying parallel with the axis of the + cylinder are the blackest or most distinct, we know that the refracting power of that eye is deficient and the + sphere that makes the lines at right angles to the axis of the cylinder as distinct as are those that are parallel to it is the measure of the deficiency.

If the lines at right angles to the + axis are the most distinct (blackest), we know that the eye being examined has

too great refracting power and the — sphere that makes the lines parallel to the + axis as distinct as are those at right angles to it is the measure of the excess power. If the vision of an eye be improved by holding the + axis over the axis of a + cylinder in the trial frame, the power of the latter should be increased.

If the vision be improved by holding the + axis over the axis of a — cylinder in the trial frame the power of the latter should be decreased.

If the vision be improved by holding the + axis at right angles to the axis of a + cylinder in the trial frame, the latter should be decreased. If the vision be improved by holding the + axis at right angles to the axis of a — cylinder in the trial frame, the power of the latter should be increased. Any change in the power of the correcting cylinder may necessitate a change in the sphere being used; this change is usually in the opposite direction to that made in the cylinder.

For instance, if the power of a — cylinder be increased and there is a — sphere before the eye, the power of the sphere may be decreased; on the other hand, if both lenses are + and the cylindrical power be increased, the probability is that the spherical power may be decreased, but if the power of either cylinder be decreased, the chances are that the spherical power may be increased.

A low degree of astigmatism and its axis may also be determined by use of the cross cylinder. We will suppose that no cylinder is before the eye, but that a low degree of astigmatism is suspected, by placing the + axis of the cross cylinder first horizontal and then vertical and determining which position, if either, is preferred by the patient, we will be able to choose a weak cylinder that will improve the vision. Slight corrections of axis may also be determined by the use of a cross cylinder. We will suppose that the axis of the correcting cylinder is at 90 degrees; by first placing the + axis of the cross cylinder at 80 degrees and noting the vision in that position, and then placing it at 100 degrees and noting whether the vision is the same, or better. If better, the axis

of the correcting cylinder should be shifted a little towards 100. The sphero cylinder form of cross cylinder being less difficult to grind, are cheaper and as a rule more accurate.

THE CROSSED CYLINDER IN SUBJECTIVE REFRACTION.

The crossed cylinder, as its name implies, is a pair of cylinders of equal strength, one being convex and the other concave, with their axes at right angles to each other. Such a pair of crossed cylinders are of course equivalent to a sphero-cylinder. Two combinations are desirable, as follows: One — 0.25 sph. $\subset$ + 0.50 cyl. and the other — 0.50 sph. $\subset$ + 1.00 cyl. These lenses are mounted in a rim with suitable handle upon which the strength of the cylinder is stamped.

The direction of one or both axes are indicated by suitable marks on the lens. If both axes are indicated, the + axis would be indicated by a white and the — axis by a red mark, these marks of course being at right angles to each other. Such lenses are or should be considered as trial case accessories. They are intended to determine the cylinder and axis required in cases of astigmatism. They are to be used as follows: A correction approximately right is placed in the trial frame. This approximation may be arrived at by the shadow test, ophthalmometer, stenopaic slit, astigmatic charts or by trial lenses, or the crossed cylinder may be held over a lens which is being worn, provided the axes of the cylinder, if there be one incorporated in the lens, is dotted.

Before proceeding to an examination with the crossed cylinder, the approximate correction before the eye in the trial frame is to be tested with plus and minus spheres to make sure that no improvement can be made by changing the sphere.

The crossed cylinder is then held before the eye under examination with one of its axes parallel to the axis of the cylinder in the trial frame, and then turned so as to cause the other (opposite) axis to occupy the same direction. The person under examination is asked to state which of the two

directions gives the better vision, i. e., with the plus or minus axis parallel to the axis of the trial cylinder. The latter is then to be changed in accordance with the person's statement. If he states that the vision is better when the plus axis of the crossed cylinder coincides with the plus axis of the trial cylinder, the latter is to be replaced by a stronger cylinder; if the minus axis so coinciding is preferred, the trial cylinder is to be weakened.

If the trial cylinder is concave, the crossed cylinder gives similar indications, i. e., to strengthen or weaken the cylinder according as the correspondence of the minus or plus axis of the crossed cylinder gives the better vision.

After every change made in the strength of the trial cylinder as suggested by the crossed cylinder, the sphere of the trial combination must be re-tested with plus and minus spheres to determine whether it is to be increased or diminished.

The axis of the trial cylinder is also to be re-tested after any change made in the sphere or cylinder. The examination with the crossed cylinder is to be repeated in the way just described after any change made in the sphere or cylinder until the crossed cylinder leaves the sight unchanged in either position, or when this is not attainable, until the change suggested by it in one direction is, after such change has been made, to be again reversed, i. e., the cylinder is now in equilibrium. The crossed cylinder now indicates that the true cylinder required is midway in strength between two successive ones of the trial case.

Where the best approximate correction is a sphere only and no cylinder seems required, the crossed cylinder is also of use. Held in different positions it may suggest that one meridian is somewhat different; a weak cylinder, say a $+ 0.25$ or $- 0.25$, is placed in the position indicated, the crossed cylinder will show whether it is to be retained, increased or rejected. Both plus and minus cylinders may be tried successively in axes indicated by the crossed cylinder.

If the approximation is a cylinder only and no sphere seems required, this cylinder is to be tested with the cross

cylinder as before; plus and minus spheres are to be tried after any change in the strength of the cylinder just as if a sphere formed part of the correction. A sphere may be accepted when the correct cylinder has been found.

Of the two crossed cylinders the stronger is useful where the astigmatism is considerable, the changes it indicates being greater. Even in cases where the difference between the meridians is considerable the weaker crossed cylinder may be employed in the final determination.

It is to be borne in mind that the person under examination is not asked whether the crossed cylinder improves the vision—it may even make it worse—but which of the positions is the better, or less bad.

An illustrative case may serve as an example.

Suppose the true refraction of an eye to be expressed by the formula $+ 1.75 \text{ sp. } \odot + 1. \text{ cyl. ax. } 90^\circ$, and that a $+ 2.25 \text{ sp. } \odot + .50 \text{ cyl. ax. } 90^\circ$ has been placed before the eye as an approximate correction; although neither this sphere nor cylinder is the true one, one meridian is corrected by them, namely, that of 180° (being $+ 2.75$), and no sphere is capable of improving this combination, but both plus and minus spheres will make the sight worse.

The crossed cylinder in its two positions will give the following results, respectively: (a) With the plus axis of the crossed cylinder parallel to the axis of the trial cylinder ($+ .50$) we have $+ 2 \text{ sp. } \odot + 1 \text{ cyl. ax. } 90^\circ$, and (b) with the plus axis of the crossed cylinder at right angles to the axis of the trial cylinder we get, $+ 2.50 \text{ sp.}$ The first being nearer the true correction, will be preferred as giving the better vision. Making the change indicated, the trial cylinder ($+ 0.50$) is strengthened somewhat, being replaced by a $+ 0.75 \text{ cyl.}$, the combination now being $+ 2.25 \text{ sp. } \odot + 0.75 \text{ cyl. ax. } 90^\circ$. Plus and minus spheres held before this will indicate that the sphere is to be reduced; replacing the 2.25 sp. by a 2 sp. , and re-examining with the crossed cylinder the two following combinations result: (a) With the plus axis of the crossed cylinder parallel to the axis of the trial cylinder we get $+ 1.75 \odot + 1.25 \text{ cyl. ax. } 90^\circ$, and (b) with the crossed cylinder in the opposite position, $+ 2.25 \odot + 0.25 \text{ cyl. ax.}$

90°. The first is evidently the better. Making the change indicated we have $+ 2$. sp. $\ominus + 1$. cyl. ax. 90°. Trial by spheres now indicates that the spherical portion of the combination is to be reduced to $+ 1.75$. The crossed cylinder would now show no preference, held in either position, nor can the combination be improved by plus or minus spheres.

As mentioned before, the axis of the cylinder is to be re-tested after any change in the sphere or cylinder. For the sake of simplicity we have assumed that the trial cylinder has been correctly placed in the example.

The cross cylinder method of correcting presbyopia is useful.

The added power, $+$ or $-$, required by any patient when reading at their accustomed distance, may be determined by the cross cylinder method of testing for a presbyopic correction. Even the eyes of illiterates may be tested by this method, for only a comparison as to the blackness or distinctness of lines at right angles to each other is necessary.

The first step to an understanding of this method of testing is a thorough knowledge of the effect of placing a cross cylinder before an emmetropic eye, or an eye that has been rendered emmetropic by suitable lenses. With this knowledge the use and value of this method will be clearly understood.

If we place before an emmetropic eye a cross cylinder having $+ 0.50$ power, axis 180, and a $- 0.50$ power, axis 90, the eye will see the vertical and the horizontal lines of an astigmatic chart equally black and distinct, and the oblique lines will be blurred.

If, when the axis of the $+$ cylinder be placed horizontal before an eye free from astigmatism, we find that the vertical and the horizontal lines are seen equally distinct, we know that the eye can focus the chart perfectly. But if the lines parallel to the axis of the $+$ cylinder are the blackest, we know that the eye has not sufficient refracting power, and the $+$ spherical lens that makes both the vertical and the horizontal lines equally distinct is the amount that the eye is deficient. If the lines parallel with the axis of the $-$ cylinder are the blackest, we know that the eye has more than sufficient power to focus for that distance, and the $-$ spherical lens that makes both

the vertical and the horizontal lines appear the same is the excess refraction present.

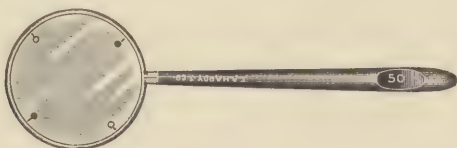
In such a test the — 0.50 cylinder calls for a half diopter of extra accommodation, for the horizontal lines and the + 0.50 cylinder, axis 180, relieves a half diopter of accommodation for the vertical lines. Therefore if the eye being tested favors either set of lines the lenses are either too weak or too strong.

When making this test the patient should hold the chart at the distance he wishes to hold his paper or do his work. This distance varies somewhat. Some desire to read or work at 30 centimeters; others at 33 centimeters, or possibly 36 centimeters.



Cross cylinder chart
for presbyopic
correction.

A suitable chart for making this test is illustrated below. The chart should be held so that the lines are vertical and horizontal and the axis of the + cylinder should be parallel to the horizontal lines.



JACKSON-STEVENSON CROSS CYLINDERS

Made in 1½-inch size with lens partly drilled to indicate axis. Minus indicated by red and plus by white filling. Made with tapered handle 3¼ inches long, with focus stamped in handle. Made in Sph. Cyl. form. May be procured in strengths of .12 .25 .50 .75 1.00 D.

CLINICS IN FRAME FITTING.

In the fitting of spectacles or eyeglasses there are many points to be considered. The most important one, of course, is the holding of the lenses in the correct position before the patient's eyes, for we must remember that the lenses are to be as far as possible a part of the eyes which they are to aid.

We must consider also seriously the cosmic effect of the glasses, for the patient may not be as pleased with him or herself when their glasses are adjusted as they are without them. If they are not the glasses will not be worn. As a rule, glasses may be so adjusted that Miss Grace will be better pleased with herself when she has them on than she is with them off. This most desirable condition is to be seriously considered when undertaking the adjustment of a pair of lenses. The features of the young lady that we are to adjust glasses for today are not perfectly symmetrical. She is conscious of this fact, and also fearful that the wearing of glasses will magnify the irregularity rather than otherwise. Her R calls for $+ 1.25$ spherical lens. The irregularity mentioned above consists of one eye (the left) being about 3 mm. above the other, and it is also set deeper in the head than its mate, so that in mounting the lenses these positions must be noted and the lenses so mounted that their optical centers will coincide with the centers of the pupils.

We must also study to please our peculiarly sensitive patient. When the patient's eyes do not lie in the same horizontal plane the lenses should be decentered up or down, or both up and down, so that their optical centers will be in the correct position when the front of the frame lies perfectly horizontal.

We will therefore order the left lens decentered up $1\frac{1}{2}$ mm. and the right decentered down $1\frac{1}{2}$ mm. This will bring the optical centers correct. We find upon trying different bridges that the bridge numbered "M- $\frac{1}{2}$, L. S." is the one most suitable to our patient. This bridge is 15 mm. wide at its base; is $\frac{1}{2}$ mm. high; its crest is on line with the plane of the lenses, and its total length is 20 mm. With the crest of this bridge resting properly on the patient's nose the lashes of the right eye just clear the lenses, but those of the left eye

are some 5 mm. away. We will therefore cut $1\frac{1}{2}$ mm. from the shank, carrying the left lens. This will set the left lens back closer to the eye, bringing the left lens to about the correct position, and will make the recession of this eye less noticeable. As stated above, the total length of our bridge is 20 mm. This we will subtract from our P. D., which is 58 mm., leaving as the length of our lenses 38 mm. This is the standard length of a 00 eye short oval lens. We will therefore insert in our R, under head of "size of eye," "00 S. O.," and for our P. D., "58 mm.," and for bridge measurements, "height $\frac{1}{2}$ mm.," "inclination for right eye," "0," and for left eye, "+ $1\frac{1}{2}$ mm." We find that the standard angle of crest, 45 degrees, does not lie flat on the patient's nose when the temples rest on the ears, but by tilting the top of the lens forward 15 degrees the bridge rests correctly. We add this 15 degrees to the 45 degrees of our standard angle. This gives 60 degrees, or the angle of our crest. This we note in our R and also note that the width of base is to be 15 mm. All the other dimensions of our standard frame being correct, we will omit filling the other blanks. The lenses ordered are large for our patient, especially in the vertical meridian, but we wish to get the periphery as far as possible from the pupils, to the end that the difference in the height of the eyes will not be as noticeable when the glasses are worn as it is without them. We recommend a gold R. B. rimless spectacle as being the most suitable for our purpose. We therefore note under head of "frames or mountings" "gold R. B. rimless."

Our R is now complete. It calls for + 1.25 lenses; the right to be decentered down $1\frac{1}{2}$ and the left up $1\frac{1}{2}$ mm. mounted in gold R. B. rimless mountings. Size of eye 00 S. O. The bridge measurements are: Height, $\frac{1}{2}$ mm.; inclination for right, 0; for left, + $1\frac{1}{2}$ mm. Angle of crest, 60 degrees; width at base, 15 mm. All other dimensions being standard, are omitted.

CLINICS IN FRAME FITTING.

Our patient, a gentleman of some fifty years, desires spectacles for reading only. The prescription calls for + 1.50 spherical lenses. They are to be mounted to suit the

patient, who decides to have a gold riding bow rimless spectacle. We must mount these lenses so they will be attractive in appearance. The mountings must be neatly fitted to the patient's face and adjusted in a manner that will give him the least possible discomfort and the greatest possible vision, so that they may prove satisfactory in every way, both to the patient and to his family and friends. We will use a mounting made of 14 K. gold with medium weight wire temples and a heavy bridge. We will say here that the bridge of a spectacle is its backbone and should be strong enough to keep its shape, for if the bridge is out of shape the lenses will not occupy the desired position in front of the patient's eyes.

They would then lose part of their effect and might even be harmful to the patient, and besides would certainly be unsightly in appearance.

We will first ascertain the interpupillary distance, and when taking this measurement will allow the patient to converge to a point approximately fourteen inches, as this will be about the distance that the reading matter will be held from his eyes.

We therefore direct the patient to look steadily at a pencil which we hold in front of our forehead.

We hold our vest-pocket rule across the patient's nose with one end at the inner edge of the pupil of the right eye and note where the outer edge of the pupil of the left eye comes.

We find the distance to be 65 mm. This we note in our prescription blank under head of P. D.

We now select a frame from among our fitting samples which we think will come near fitting the patient. We have chosen the one marked N2 00 eye. The bridge of this frame is 6 mm. high, 18 mm. wide at its base and its crest is $1\frac{1}{2}$ mm. forward of the back plane of the lenses, which are 23 mm. apart. Upon placing this frame upon the patient's face with the crest of the bridge at its proper place, we are able to determine what changes, if any, are desirable. We first note that the size of the eye is too small and that the P. D. is too narrow, but that the bridge fits the patient's nose except that it is a trifle narrow at its base. We also find that the crest does not lie perfectly flat on the nose, but by raising the temples a little above the

ears, that it does. We also find that the lenses occupy the desired position in relation to the lashes, for they just clear them, and with the temples raised they are in the correct position vertically for reading, being slightly pantoscopic. We are now ready to complete our formula for the dimensions of the lenses and mountings. To determine the size of eye we will subtract from the P. D., which is 65 mm., the distance between the lenses, or that space occupied by the bridge, which is 23 mm. This leaves 42 mm. for the length of the eye, and for width we will make them 2 mm. wider than are the sample lenses, which are 31 mm. We therefore note in our prescription for size of eye 33 by 42 mm. These lenses will provide a large field for our patient and will also be in keeping with his features, which are large. Under head of height of bridge we will note 6 mm., the same as our sample, for our patient, when looking at his paper, will look through the lenses just below their center. For inclination we will note + or forward $1\frac{1}{2}$ mm., and for angle of crest we will note 45 degrees, same as sample, because we found that the crest rested correctly when the temples were raised slightly above the ears. As stated above, the base of the bridge is a trifle narrow. We will therefore note width of base 19 mm., or 1 mm. wider than is the sample. Our sample frame is too narrow between the temples, but the lenses prescribed will make the width between the temples 4 mm. greater than is the sample, and this we think will be correct. We therefore omit filling this blank and pass to length of temple, which we find should be $\frac{1}{2}$ inch longer than the sample, which is 6 inches. We therefore note for length of temples $6\frac{1}{2}$ inches, and will adjust for length to back of ear when our patient calls for his spectacles. Our last notation to make is the angle of joint, which we will make 10 degrees (pantoscopic). This will bring the temples down upon the ears and allow the lenses to tilt back a little so that the line of vision when reading will also be at right angles to the plane of the lenses; in other words, he will look straight through the lenses when reading. When our patient calls for the spectacles we will make any slight changes that may be needed, such as adjusting the temples so that there will be no pull at back of ear or undue pressure on the nose.

CLINICS IN FRAME FITTING.

Our patient, a gentleman twenty-three years of age, whose prescription calls for $+ 100 \text{ S } \subset + 150 \text{ C}$ axis 90 for right eye and $+ 075 \text{ S } \subset + 175 \text{ C}$ axis 95 for the left, wishes to be fitted with a pair of rimless eyeglasses. He states that he desires them to be correct in every detail. He also says that he has worn eyeglasses, but that they have never been satisfactory, owing to the fact that the lenses were too far from his eyes. We asked to be shown the eyeglasses in question and found, upon placing them upon the patient's nose, that the P. D. was 4 mm. too narrow and that the spring rested on his forehead, preventing the lenses from occupying a correct position vertically and also causing the patient to force them from his nose when he frowned. We also found that the lenses were 3 mm. from his eyelashes, and that the lenses were not quite correct horizontally. The tilting of the lenses forward at the top was sufficient to interfere materially with distinct distant vision.

The patient's nose is thin and rather prominent, forehead full above the eyes, which are set deep in his head. His P. D. we found to be 64 mm. The lenses that he had been wearing were 40 mm. long and they were 20 mm. apart when adjusted on his nose, thus making the P. D. of his eyeglasses 60 instead of 64 mm., his actual P. D. This practically decentered the lenses 2 mm. each, or 4 mm. for the pair. Now decentering a 1.00 D lens 10 mm. produces a 1 degree prism, and as we have in the horizontal meridian of our prescription 500 D, we would have to decenter them only 1.5 as much, or 2 mm., to produce a 1 degree prism. Therefore the decentering of 4 mm. practically placed before our patient's eye a 2 degree prism base in. This was probably one of several reasons why his eyeglass had not proved satisfactory.

The fact that the lenses were not in a correct position vertically and that they were not always correct horizontally, for the patient did not always get them on so that the axis of the cylinders were exactly right, were other reasons why they did not prove satisfactory. Now, our patient states that he desires an eyeglass that will be correct in every detail—one that will not only correct the defects in the ones

he has been wearing, but one that will be neat, stylish and comfortable—one that will give him the best vision and the largest field possible—one that will please both him and his friends. Now, it is up to us to comply with all his reasonable requests. In the first place, his eyeglasses must be neat and stylish, and he might have added that he desired a sense of security when wearing them.

We stated above that his nose was thin and prominent. This indicates that it is a good nose for eyeglasses, and as our patient has stated that he wants rimless eyeglasses we will not hesitate to give them to him, believing that he will be better pleased with them than he would be with a spectacle. Believing the new Vici to be the neatest and most stylish eyeglass mounting on the market, especially when well fitted, we have chosen that style as being best suited for our purpose, and we find that No. 123 of this style fits our patient quite well. This mounting, having a rigid bridge, will hold the lenses correct horizontally, thus securing the correct position for axis of cylinders, and the guards being made entirely of metal are susceptible of any adjustment necessary to secure a correct position vertically. The units figure 3 of the above number indicates that the crest is 3 mm. forward of plan of lenses and the 12 indicates that it is 12 mm. wide at its base. The distance between the inside edges of the lenses when set in this morning will be 22 mm.; this distance subtracted from our P. D., which is 64 mm., leaves 42 mm. for the length of lens, and as we wish to use a lens that will give our patient as large a field in the vertical meridian as possible, we will make them 34 mm. wide. We will therefore note on our prescription blank under head of frame instructions: No. 123 10 K. gold Vici; and under head of size of eye, 34 by 42; and under head of P. D., 64 mm.; and under head of position of crest we will note 3 mm. forward, as we desire to place the lens as close to the eyes as possible and not touch the lashes. We will also note that the spread of the guards when in position will be 11 mm. at the top and 14 at the bottom. We will also note under head of remarks that the guards are to be curved out at the top and faced back about 5 degrees when in position. As stated above, the guards of this mounting, being all metal,

may be adjusted or bent to any desired angle or shape. Our patient desires not only the best vision, but the largest field possible, and as toric lenses afford a larger field than the ordinary style and a much larger field than do the bi-concave, which the patient has been wearing, we will order the lenses made of that form. The deep concave curve of the toric lens affords room for the eyelashes, enabling us to place them closer to the eyes than we could the other styles. This is especially true of the periphery of the lens, the curve being such as to practically preserve the same distance between lens and cornea, therefore the same refracting power whether the patient is looking down, up, sideways or straightaway. Toric lenses not only afford a larger field, but clearer vision. The increased cosmic effect and general comfort to the wearer of these lenses are scarcely conceivable until they have been actually tried.

We therefore note under head of lens instructions: Toric style, leaving the manufacturer to determine the best base curve to use.

Our patient is instructed to call for his glasses in a day or two, when any slight adjustment that the guards may need will be attended to.

CLINICS IN FRAME FITTING.

Our patient, a lady, possibly twenty-five years old, has been wearing minus lenses for several years, the power of the lenses having been increased from time to time until she is now wearing 12.00 diopters, and the new prescription calls for one diopter more. The lenses she is now wearing are rimless, 0 eye, bi-concave. They are necessarily thick at the edges, and, of course, are quite heavy; also very conspicuous, and the patient is fearful that the new ones will add still more to these undesirable and uncomfortable features. She states that her friends annoy her by asking questions about her glasses—especially about the thickness of the lenses—and desires to know if it is not possible to make lenses that will not be so thick and heavy.

the prescribed power that will be thinner; therefore, lighter, and possibly less conspicuous, but that their cost will be much greater than for the bi-concave style.

At her request we show her an oval lenticular lens having practically the power desired, and explain its advantages. She seems pleased with the sample and decides to have the new lenses made oval lenticular. She desires to use her old mounting. We therefore inform her that the lens clamps will have to be made to conform to the thinner lenses, and this will entail an extra charge, which she agrees to pay.

To make these lenses we will have a convex spherical curve of 3.00 D ground upon the plano side of a $+10.00$ D convex cylinder, the axis of which will be horizontal. The thick edges of the lens will then be at the points where the clamps come now. Upon the cylindrical side of this lens we will grind a concave spherical curve of 16.00 D. The diameter of the depression thus made will be about 24 mm. in the vertical and 32 in the horizontal meridian, thus conforming practically to the shape of the finished lens. In mounting the concave side will be placed next to the eye. This will allow the lenses to be placed quite close to the eyes, and in order that the nodal point of this lens shall occupy the same position that the nodal point of the test lens did we will cut from the shanks of the bridge $\frac{1}{8}$ of an inch. If this were not done the lenses, owing to their position, would be too weak.

We confidently expect that these lenses will be worn with a greater degree of comfort than the bi-spherical would be.

CLINICS IN FRAME FITTING.

A youth whose R calls for O. D. $+2.00 \subset +4.50$, axis 90; O. S. $+2.50 \subset +4.00$, axis 90, is to be measured for a riding bow frame. The oculist states under the head of "Remarks" that the bridge of the frame must be very stiff and that the lenses may be transposed if we think it desirable. The special instruction in regard to the bridge is a wise one, for the axis of strong cylindrical lenses must be held properly or the lenses will be of little value, and the bridge being practically the backbone of the spectacle, should be very strong.

It is now almost universally acknowledged that the periscopic principle has great value. We will therefore transpose the above R to the end that the lenses will have the periscopic effect in the vertical meridian, this being the meridian most used. The transposed R reads O. D. $+ 6.50 \subset - 4.50$, axis 180, and O. S. $+ 6.50 \subset - 4.00$, axis 180. This form of lens may be placed much nearer to the eye than the bi-convex form could be, and the lower part of the lenses, if properly adjusted, will curve back so much that their edges will be out of the way when the wearer is looking down, as when reading.

A concave cylindrical curve of three to five diopters, when the axis of the cylinder is horizontal, or nearly so, provides a periscopic effect in the vertical meridian that very materially enhances the value of the lenses to the wearer. The distance between the surface of the lenses and the cornea is more nearly maintained, whether the patient is looking down or straight-away, if the surface next to the eye has such a curve. The maintaining of this distance is of great value in a lens of this power, and the ability to always look straight through the lens, whether looking at a distant object or reading, is also of great value.

The measurements for the bridge of this spectacle are taken in the usual way. The pupillary distance is measured with great care to the end that the lenses may have their optical centers correct when worn. Great care is also used when measuring the inclination of the bridge, as we wish to place the lenses as near to the eye as is possible and not have the eyelashes sweep them.

The largest lens compatible with the patient's features is also ordered.

CLINICS IN FRAME FITTING.

Our patient is a gentleman fifty-two years old. His distant correction for right eye requires $+ 1.50$ sphere $\subset + 1.00$ cylinder, axis 80, and for left eye, $+ 1.50$ sphere $\subset + 1.25$ cylinder, axis 100, and to the above must be added $+ 2.00$ for near vision. The patient states that he has never worn

bifocal lenses, but prefers that style to two pair of glasses, provided the bifocal style can be recommended. We inform him that bifocal lenses, when properly constructed and correctly mounted, rarely, if ever, fail to prove satisfactory. We suggested that the distant lenses be given the deep periscopic form, and that the segments used be of the opifex style. We also recommend the fused bifocal style provided the lenses are given the above form. We also inform the patient that the most satisfactory way to mount lenses made according to the above formula would be in a riding bow spectacle, which might be either rimmed or rimless, as he preferred, telling him that such a spectacle would maintain the cylindrical lenses at their proper axes; that they could not fall off no matter what position his head might be in, and that the lenses for both distant and near vision could be perfectly centered.

In regard to rimmed or rimless, we recommend the latter, for the reason that they are neater in appearance, less conspicuous, lighter in weight, and have no rims to interfere with vision or annoy the wearer. They are less durable than the rimmed spectacles, but for an adult who desires to wear them constantly, they are, everything considered, more desirable than the rimmed style.

The rims of spectacles not only interfere with vision, but they also add weight to the spectacles and make them much more conspicuous.

We also recommend gold as being, by virtue of its superior wearing qualities and its great elasticity, the most satisfactory metal to use for the mounting.

If bifocal spectacles are to be worn with comfort, the following conditions must be met:

First, the optical center of each lens must be located directly in front of the pupil of each eye, both when viewing distant objects and when reading.

Second, the lenses must be so far removed from the eyes that the patient's lashes do not come in contact with them.

Third, the long diameter of the lens must be horizontal to afford a wide field of vision laterally.

Fourth, both lenses must lie in exactly the same plane, and this plane must be at right angles or as near as possible to the

direction of vision, both when the patient is reading and when looking at a distance.

Fifth, the lenses must be as large as can be worn to the end that the widest possible field be obtained.

Sixth, the bridge of the spectacle must be of the proper width and height and it must be perfectly flush with, or flat upon, the patient's nose.

Seventh, the temples must be of the proper length; they must pass loosely over the ears, and be far enough apart to avoid undue pressure on the sides of the face.

Our patient having decided to leave the construction and mounting of the lenses entirely to us, we will first note in our prescription under the head of "Lens Instruction," that the lenses are to be ground peritonic. (Compound lenses having the deep periscopic form.) These lenses will have convex toric curves on their anterior and concave spherical curves on their posterior surfaces. The convex curve in the meridian having the least refraction will be 6.00 D, and the concave curve 4.50 D.

Under the head of "Style of Bifocal Lenses" we will note "Opifex." This means that a small and practically round, and very thin wafer, having an edge like a keen blade, will be cemented to the lower half of the distant lenses. The shape and thickness of this wafer will make it almost invisible. It may be decentered in, as much as is desired for the purpose of placing the optical center of the reading lenses correctly.

Under the head of "Style of Frame or Mounting" we will note "10 K. R. B. Rimless, with extra heavy bridge.

The bridge of a spectacle being practically its backbone, causes us to note "extra heavy."

We will now proceed to measure the patient's face. A bridge is chosen by selecting one from among our samples that practically fits the patient's nose. This one is numbered M2. It is 15 mm. wide at its base and is 6 mm. high. This is 2 mm. higher than would have been chosen if the lenses were not to be bifocal.

The crest of this bridge is 2 mm. forward of the back plane of the lenses, yet the patient's lashes sweep them when he closes his eyes, but the lenses in the trial frame are ordi-

nary periscopic and those ordered will have the deep periscopic form, thus affording about 2 mm. more room for the lashes. This we consider sufficient. We will therefore note under head of "Bridge Number" "M2."

We now measure the pupillary distance with our pocket rule and find it to be, for distant vision, 63 mm., and for near vision 60 mm. We therefore note under head of "P. D." "For distance 63 mm. and for reading 60 mm." The optician will then decenter in the scales $1\frac{1}{2}$ mm. each.

We now measure the length (total) of our bridge and find it to be 22 mm. This we subtract from our P. D., which is 63 mm. This leaves 41 mm. for the length of our lenses. This being the standard length of a 000 eye we will note under head of "Size of Eye," "000."

We next note the angle of crest and find that the crest of our sample bridge has the proper angle for our patient, and knowing that it has the standard angle (45 degrees) we omit entering this angle on our prescription.

We next measure the temple distance. This we find to be 120 mm., or just 6 mm. wider than will be the front of the spectacle as ordered, viz.: Length of two end pieces, 10; length of two lenses, 82; and length of bridge, 22; total, 114 mm. This leaves 6 mm. for the outflare of the temples.

We will therefore omit giving temple distance as we did angle of crest.

We next measure distance to back of ear. This distance we find to be 115 mm. This will require a total length of $6\frac{1}{2}$ inches (163 mm.). We therefore note under head of "Length of Temple," $6\frac{1}{2}$ inches.

When bifocal lenses are to be worn great care should be used in noting the angle of joint. By placing the trial frame upon the patient and letting him look at a card held at the reading distance we will be able to determine how much, if any, the lenses should tip forward at the top to enable the patient to look straight through them when reading. In this case we will order the joint pantoscopic, 5 degrees.

CLINICS IN FRAME FITTING.

A young girl is to wear $+ 1.50$ Spherical Lenses. We note that the patient's face is small; eyes close together; nose thin and rather prominent for one of her age, and that her eyelashes are quite long.

We are to mount the lenses in a riding bow spectacle frame—the patient's age precluding the wearing of eyeglasses or the use of rimless lenses. We note also the oculist has suggested that a gold frame be used, probably for the reason that gold is by far the most suitable metal for a patient of tender years.

We first measure the inter-pupillary distance with a vest pocket rule graduated in millimeters—directing our patient to look steadily at a picture across the office. We measure the distance between the inner edge of the pupil of the right eye and the outer edge of the pupil of the left eye and find this distance to be fifty-two millimeters. This we note in our prescription blank under head of "pupillary width." We now select a frame from among our samples that has a narrow bridge of medium height and one having long shanks. The one selected is numbered M—1; L. S. The dimensions of this bridge are: Width between eye wires, nineteen millimeters; height, three millimeters; base, fifteen millimeters; its crest is on line with the eye wires and the angle of crest is forty-five degrees. We place this frame upon the patient and note that when looking at the floor across the office she looks through the horizontal center of the lenses. We, therefore, decide that the height of the bridge selected is correct, and therefore note in our prescription under head of "height of bridge," three millimeters.

We next determine the position of crest. We step to the side of our patient and ask her to look at our pencil and to follow it as we move it slowly up and down before her eyes. We carefully note whether the lashes sweep the lenses or not when she partially closes her eyes in looking down. We first note one eye and then the other, and after being sure that the lenses are as close to the eyes as they can be and clear the lashes we note under head of "position of crest" on line or O.

We next note whether the crest of the bridge lies flat on

the patient's nose when the temples rest upon the ears, and upon finding that it does we note under head of "angles of crest," forty-five degrees. We might have omitted to make this notation, for we know that if no angle of crest is noted the manufacturer will furnish one of forty-five degrees, this being the standard angle.

We next note the width of the bridge at its base and find that it is a trifle too wide. We, therefore, note under head "width of base," fourteen millimeters. We do this because we wish the spectacle to be held rigid, and also to have a part of the weight of the spectacle borne by the sides of the nose, for if it is the patient will be more comfortable.

We will now determine what size of eye to prescribe. We know that our P. D. is fifty-two millimeters and that our bridge will be eighteen millimeters between the eye wires; therefore the length of our lens will be fifty-two minus eighteen millimeters, or thirty-four millimeters. This is the length of a standard three-eye, but desiring to prescribe the largest eye compatible with the patient's features and knowing that a two-eye will enlarge the field, we will order a two-eye. This will necessitate bending the shanks of the bridge in practically one millimeter each. This can be done without destroying its symmetry.

We next note the width between temples three-fourths of an inch back of the joints. We find this distance to be one hundred millimeters. This is practically what the frame we have prescribed will measure. Our two lenses measure seventy-two millimeters; the bridge seventeen millimeters and the end pieces practically twelve millimeters, or six each, making 101 mm. We, therefore, omit recording on the prescription the temple width.

We next note the length to back of ear, measuring from the inner edge of the joint to the back of the patient's ear. This distance we find to be ninety millimeters. This we note and also the total length of the temple, which for this patient should be one hundred and twenty millimeters.

PLIERS.

In the manufacture of optical pliers it has been necessary to have a different plier for each bend on spectacles and eye glasses which are being molded to conform to a R , in order to save the chances of marring, especially on new goods. We shall in the following article explain each plier and its special use. For shaping and adjusting pliers are made with the following jaws as illustrated, A, B, C, D, E, F, G, H, I, J, K and other styles are shown and described by name. We strongly recommend, as by far the best pliers for use, heavy long-handled ones.

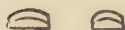
 Style "A" are used for gripping the shanks of a spectacle bridge when it is necessary to bend them up for the purpose of lowering the lenses, or down to raise the lenses. It has flat, broad jaws, which afford greater purchase and so lessens the chances of the plier slipping.

 Style "B" are used principally for rolling shanks of bridges or arms of eye glass guards for the purpose of setting lenses in or out. As the metal rolls over the round jaws it molds smoothly and evenly and has less tendency to mar them.

 Style "C" are the most used for general adjusting of spectacles and eye glasses. Their long, snipe-pointed jaws allow one to grasp a hold on guards or shanks which have been bent very sharply, and at the same time the jaws being flat, afford purchase enough to avoid slipping. These pliers are used to make the general measurements conform to the dimension not in the R ; "A" and "B" pliers being used to finish the bending where the sharp corners of the "C" plier would mar them.

  Styles "D" and "E" are used to bend a flat surface into a curved one. These pliers have one convex and one concave jaw. Both of them have the same radius of curvature. They are used principally for spectacles, to make the bridge narrower by gripping the bridge at the crest. They are also used for spreading temple width by gripping the temples just back of the end pieces;

also to curve the ends of temples back to keep them from irritating the lower lobes of the ears.



F

G

Styles "F" and "G" are constructed the same as "D" and "E," but the radius of curvature is less, which makes them more adapted to eye glass adjusting. They are used to narrow springs or to mould the face of guards to conform to the contour of patient's nose. Their radius of curvature is less than "D" and "E," thereby allowing a much sharper bend.



H

Style "H" are used to make very narrow pupillary distances in spectacle bending. By gripping the shank at the end nearest the glass with the round jaw on the temporal side of shank and the flat jaw on the nasal side, we are permitted to roll the shank to a very acute angle, and consequently produce a narrow pupillary distance. The two jaws are made in this manner especially for this work, because they cannot mar either side of the shank.



I

Style "I" are used for flattening out a nosepiece, using the convex jaw on the under side of the bridge and the flat jaw on the top. They are also used to take out a kink in a damaged eye wire which requires a convex broad jaw for the inner side of the eye wire and a broad flat jaw for the outside.



J

Style "J" are used in conjunction with Style "A" for tilting joints on spectacle frames. Hold the joint close up to the rim with Style "J"; then twist the joint with Style "A" the desired amount to tilt the lenses for near work. They are used also to true up joints, which cause the temples to slant up or down, when the front is in perfect alignment. Hold the joint with Style "J" as before, and the end of the joint with Style "A"; now bend the end of the joint up or down as the case requires in order to have the temple line up straight across the front.



K

Style "K" are used for gripping the stud of an eye glass when one wishes to tighten a stud screw. The two notches in plier which engage the stud make it impossible for the stud to turn, and at the same time holding the stud securely saves the chances of breaking a lens, which so often occurs when hold-

ing the stud between the fingers. This plier may also be used while holding the stud as before described, when we want to bend the spring in order to lower or raise the outer end of a lens.



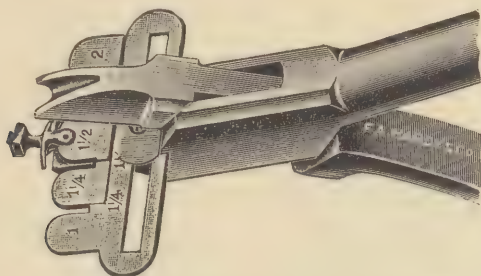
THE HARDY SHANKING PLIER



PETERSON SHANKING PLIER

Under the head of "Shanking Pliers" are illustrated two styles—the Hardy Shanking Plier and the Peterson Shanking Plier. The Hardy plier is used to grip the shank of a spectacle rim or rimless mounting at the end where it joins the eye wire or lens strap and accomplish a neat bend close up to the foot of the bridge.

The Peterson plier is used for frames or rimless mountings without removing the lens. It has a groove in the end which the strap or rim sets into, and a two-hooked jaw on one side which grasp the shank and the bend is made in the same place as the Hardy plier.



THE HARDY STRAP SHAPING PLIER

As the illustration shows, this plier is made with a sliding

bar at right angles to and between two flat broad jaws. The bar has six solid lugs, varying in thickness of $\frac{1}{4}$ mm. each. Between each lug is a notch also varying in width of $\frac{1}{4}$ mm. each. By inserting the end of the lens into the notch that fits we are enabled to tell to the fraction of a millimeter the size we must shape the strap to fit the lens. Then by inserting the lug of the corresponding number as the notch into the rimless strap, and with one squeeze of the plier we have shaped the strap to exactly the same thickness as the lens. With this plier we can change a standard strap of 2 mm. width to a strap $1\frac{1}{4}$ mm. in width, or to one 3 mm. in width, or vice versa.

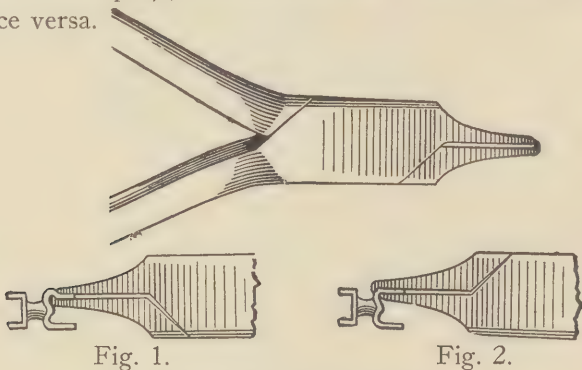
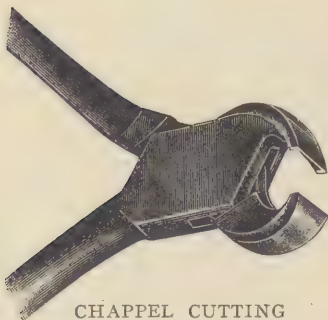


Fig. 1.

Fig. 2.

THE GLOBE STRAP PLIER.

Strap pliers are used to make rimless straps narrower or wider. Fig. 1 shows the plier being used to make a strap narrower, and Fig. 2 shows the same plier being used to make a strap wider.

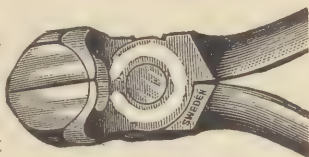


CHAPPEL CUTTING

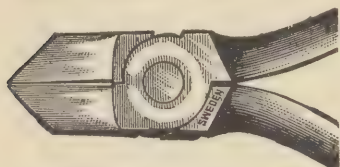
Cutting pliers are made in three styles. The Chappel plier is the best made for use on rimless screws and all soft metal screws. The illustration shows the square lugs which prevent the jaws from jamming the cutting edges and consequently keeps the edges always very sharp. Glass screws cut with this plier need no burnishing,

because the ends are cut off even with the surface of the clamp. There is also no forward jump in cutting, thus preventing lenses cracking from the jar caused when cutting with the ordinary cutting plier.

The Swedish End Cutting Plier is the ordinary plier used for cutting any style screws and material. The cutting jaws close and cut evenly, but it is necessary to bur-nish rimless screws after cutting.



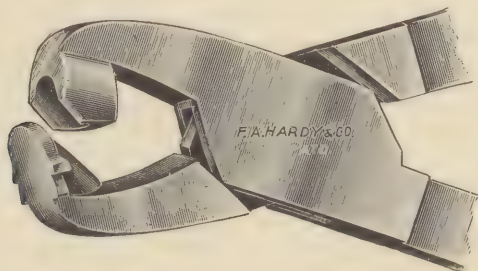
SWEDISH END CUTTING



SWEDISH SIDE CUTTING

The Swedish Side Cutting Plier is used the same as the end cutting plier. The jaws open and close much like the blades of a scissors, and for this reason must be kept sharp or else screws might slip and cause much annoyance.

Probably nothing causes as much discomfort to a patient wearing spectacles as an ill-fitting angle of crest. With the Hardy Crest Rolling Plier it is possible to roll a crest having a normal angle (45 degrees) to 35 degrees, more vertical; or to 15 degrees, more horizontal, thus making any angle from 80 degrees to 30 degrees. The jaws are so constructed that the bridge is held very securely, thereby causing no plier marks



THE HARDY CREST ROLLING PLIER.

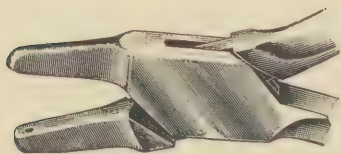
and eliminating all polishing of the bridge. This is very essential, especially in changing the angle of crest of gold filled bridges, as many bridges are ruined by polishing after bending. This plier may be used for M, N or O widths at

base, making it really three pliers in one. It is made with long, strong handles, which make it easy to make a desired change with very little pressure.

Always use the plier with the concave jaw on top, and to make the crest more horizontal, insert the bridge into the plier with the posterior edge of crest pointing toward the handle end of plier and the temples pointing down and back.

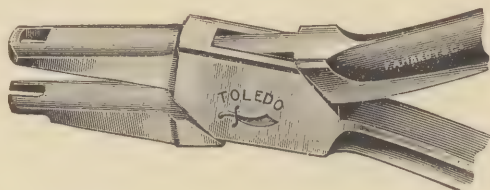
To make the crest more vertical, insert the bridge into the plier with the posterior edge of crest pointing up and forward and the temples pointing down and forward.

Care must be taken in each case to insert the bridge under the lugs at each side of the plier, and with a very little practice you determine how much pressure to use to make the desired change.



The Vici Plier is used in adjusting finger piece mountings. Each jaw has a hole drilled in it, and by grasping the bridge exactly over the screw which holds the guard and spring on, it is

possible to bend the bridge in order to raise or lower the outer end of a lens. The screw fastens itself into the hole of the plier and prevents slipping, and also does not disarrange the spring and washer which is so liable to happen with any other style plier.



The above illustrated plier is used for assembling regular offset guard eye glass mountings. By inserting the arm of the stud into the hollow chop jaw and the box of the stud into the square hole in the other jaw, one can tighten the stud screw or tilt the spring very easily and have no risk of breakage or slipping. Both jaws are made concavo-convex, so that they can be used for adjusting also.



ASSEMBLING PLIER.

The above illustrated plier is used for assembling coil spring finger piece mountings. Hold the guard and washer in place on the bridge, then set the spring in place and fasten the screw. This plier can also be used for adjusting the bridge. The faces of this plier are curved, which makes it possible for use as a tilting plier for spectacle end pieces.

SIMPLE MAGNIFIERS.

In its simplest type the image forming lens is represented by a pocket magnifying glass. If such a glass be held so that one of its surfaces faces the sun, and at a little distance beneath the other surface a white paper is held, with its surface lying in the same plane as the plane of the lens, and the lens be properly adjusted between the sun and the paper, a small image of the sun will be seen projected upon it. The sun is then said to be focused upon the paper.

The distance that the paper is from the center of the lens represents the focal length of the lens. The paper is then at the principal focus of the lens.

The most important characteristics of every lens is determined by its principal focal length. For the sake of illustration we will suppose a lens to have a focal length of two inches. Now in any room in which you may happen to be, having a light wall paper on, or a white wall, and at a time when the window is highly illuminated from without, hold your magnifying glass directly in the path of light from the window, and at some little distance from the wall, when you will find that an optical image, or picture of the window frame or lattice work, will be projected by the lens upon the wall. This simple and familiar experiment of projection by a lens serves to ex-

plain more than half of all the effects we reach by means of optical apparatus.

In such a case both the object and the image are removed from the lens by a distance greater than its focal length. If the object be nearer the lens than its principal focus or focal length, there will no longer be a projected image such as can be exhibited on a screen, but on looking through the lens a magnified image of the object will be seen.

Position of Observer's Eye.

The most advantageous position for the observer's eye is close to the lens, and the magnifying power will be given pretty accurately by dividing the principal focal length of the lens into the nearest distance of distinct vision usually taken as ten inches. For instance, if the focal length of the lens is two inches, and the nearest distance of distinct vision is ten inches, then ten divided by two equals five.

Therefore, when the conditions are as above, the magnifying power of a two-inch lens is five diameters, or twenty-five times. If the lens had a focal length of one inch, the magnifying power would be ten diameters, and so on. If the focal length be given in centimeters, we can make the same reckoning, taking the near point of distinct vision as twenty-four centimeters. Hence an eight centimeter lens would magnify three diameters, for twenty-four divided by eight equal three. A practical check on the figures thus obtained for the magnification is easily arranged. All that is necessary is to take from a newspaper a single column of type and cut it through its center; lay one-half upon the table about ten inches from your eyes, and then while holding the magnifying glass close to one eye, adjust the other half of the column of printed matter to that distance from the glass at which the virtual enlarged image of the type is formed about ten inches away, so that the magnified image of the type can be brought into juxtaposition with the unmagnified type seen with the other eye.

Under these circumstances one can compare the size of the printed letters seen by the unaided eye, with the size of the image of the same letters magnified by the glass. If this experiment be tried with a two-inch glass it will be found that

the magnified letters are five times the height of those seen directly. Simultaneous vision of the type and the magnified image of the type is not always easy at first, but a little practice will enable one to compare the magnified letters. If two graduated rules are substituted for the type, very accurate measurements of the power of the lens can be made.

Magnification Explained.

The magnification of objects by a single convex lens, is due to nothing else than the fact that there is a limit, about ten inches on the average, to the nearness with which we can approach an object to the eye, while seeing clearly the form and detail of that object. The nearer we approach an object the larger is the image of it formed within the eye. Hence people that are very myopic enjoy what we may term "microscopic vision," without the aid of any lenses.

If a normal sighted person could see clearly the form on an object held two inches from the eye, that object would be magnified to the same extent as has been stated above for a two-inch simple magnifying lens.

What the lens does for the object at two inches is simply to throw back an image of that object to the nearest point of distinct vision; usually figured as ten inches, and as the backward projection, takes place in straight lines, passing through every point of the object, it preserves the angular relationship of those points, so that they subtend at the eye the same angles as they would if seen at two inches.

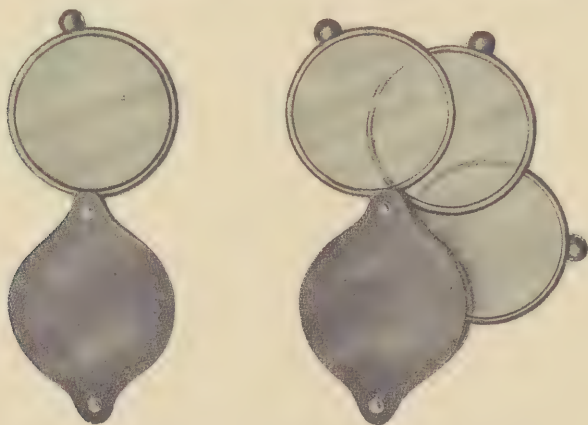
Pocket Magnifier.

Very few people, comparatively, realize the vast fund of interesting information, or the enormously extended field of observation, which is opened up with the aid of only the simplest optical apparatus. We question the application of the term liberal to any system of education which neglects the practical, every-day use of modern scientific aids to sight. There is ground for satisfaction in the more general use of spectacles by children of school age, for these are so often necessary to clear up detail within the ordinary range of vision; but there is good reason for the movement by which

spectacles have been made popular to be extended so as to bring within reach of all an observer's knowledge of the world's minutest life on the one hand, and on the other marvelous celestial objects, which have been hidden even from man's imagination until within the past few hundred years. The microscope and the telescope reveal details of the excessively minute and excessively distant which are surely of real importance to us all, if considered from an educational standpoint. And with merely a pocket lens one may find his way into a new domain of intellectual recreation enlarging in all directions his acquaintance with the marvels of nature that surround us—discovering to sight new wonders of insect and plant life; reading the inscriptions which geologists have interpreted for us in the tomb of all life, in the soils of today, and in those rocks which, as the soil and mud of past ages, became the sepulchre of past creations of living things.

Forms of Mountings.

There are a dozen attractive forms in which magnifying glasses can be had for the companionship of the waistcoat pocket. The aluminum, shell or plated mounts now obtain-



ONE LENS MAGNIFIER.

THREE LENS MAGNIFIER

able are highly finished, giving the article an elegant appearance; and the same can be said for the mounted reading glasses, which are, of course, simply magnifying lenses of low

power. Several optical devices are employed for the purpose of securing good definition together with high magnifying power. Sometimes two or three lenses are pivoted together in one mount so that they can be used together or separately; and when lenses are placed one over another, their surfaces separated by only short intervals, the combined optical strength of the several lenses is the sum of their individual strength; also the defining power of the combination is usually better than that of a single lens of the same strength—in other words, there is less aberration of the image-forming light by a lens compounded of the several magnifying glasses with shallow curves, than there would be by a simple lens of the same power with deep curves.

A BINOCULAR MAGNIFIER.

This magnifier consists of a strong straight temple open cell spectacle frame, to which are mounted cells for holding sphero-prismatic lenses. Each of the cells carrying the lenses is attached to one end of a steel spring, the other end of the



spring being attached to the bridge of the spectacle. The cells are connected by an adjustable bar. By means of this bar the lenses may be separated or approximated, as desired, for the purpose of producing binocular vision. The bar also holds the lenses in perfect alignment.

The cells are mounted at an angle so that the line of vision

is at right angles to the plane of the lenses, which are $+ 7.50 \div 5^\circ$ prisms, base in.

The Binocular Magnifier illustrated on page 275 has many advantages over anything of the kind that has yet appeared. Among these advantages are the following:

Great magnifying power with a large and perfectly flat field—there being no distortion.

Absolute and comfortable binocular vision.

Great working distance between lenses and object viewed.

Both hands perfectly free.

No obstruction to the view of surrounding objects.

Easily and quickly adjusted.

May be used in connection with a reflecting mirror or other illuminating apparatus.

May be worn over spectacles or eye glasses.

The sphero-prisms are adjustable horizontally for the purpose of obtaining comfortable binocular vision—regardless of accommodation, convergence or muscular imbalance.

These magnifiers will be greatly appreciated by eye surgeons, engravers, watchmakers, dentists, electrical workers and the partially blind; in fact, by every one wishing to see small objects more distinctly than is possible without magnification.

THE RELATIVE FOCUS AND DIAMETER OF READING GLASSES.

Magnifying lenses of low power, or those having a focal length of from 3 to 12 inches, when suitably mounted, are called "Reading Glasses."

As a rule the focal length of such a lens is twice its diameter. The focal length of a 2-inch reader being about 4 inches and that of a 3-inch about 6 inches, the refracting power of the former would be practically 10 diopters, and that of the latter $6\frac{1}{2}$ diopters, and following the same general rule, the focal length of a 5-inch reader would be 10 inches and its refracting power practically 4 diopters.

The above being true, it will be seen that the larger lenses have the least refracting or magnifying power. A lens, the

focal length of which is much less than twice its diameter, would (owing to its curvature, which alone produces refraction) be quite thick, therefore too heavy to be practical as a reading glass.

When it is known that a lens 3 inches in diameter, having a focal length of 4 inches, would be nearly round, it will be seen that high power combined with great diameter is impracticable. The field of distinct vision is limited by all magnifying lenses, and the higher the power—in other words, the shorter the focal length—the more limited is the field. As a rule the field (and what is meant by “the field” is the amount of space which can be distinctly seen through a lens) is practically one-third of its focal length. This is true no matter what its diameter is. For instance, when looking through a lens having a focal length of 4 inches at a line of type, only a little more than 1 inch of the line can be distinctly seen, provided the lens is held far enough from the type to get the best results. The field can be enlarged somewhat by holding the lens nearer to the type, but this is at the expense of magnification, as the magnifying power becomes less as the lens approaches the type.

The above being true, it will be seen that practically no larger field can be obtained with a 3-inch reader having a focal length of 4 inches than with one 2 inches in diameter of the same focal length. Achromatic readers afford a slightly larger field than others of the same power. This is also true of cross cylinder readers.

BAROMETERS.

Not many years ago few, except scientists or navigators, possessed or could afford to possess a reliable barometer or weather indicator. But since the introduction of the Me-

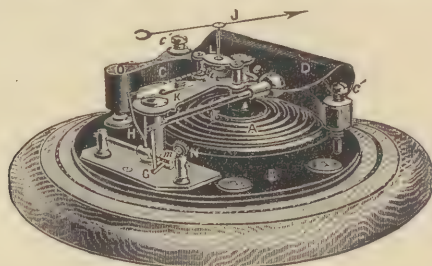


FIG. I.

chanical or Aneroid Barometer, and especially since instruments of great accuracy have been placed upon the market, at prices which are within the reach of nearly every one,



HOUSEHOLD ANEROID BAROMETER

their sale has greatly increased. A fairly good instrument can now be purchased for from three to six dollars and superior ones at from seven to fifteen dollars. There are, of course,

instruments of less and of greater value than the above quotations; some have elaborate cases; some are combined with other instruments, such as thermometers, compasses, time-pieces, etc. Such instruments are necessarily more expensive, but for practical purposes an instrument costing from five to ten dollars will register atmospheric changes promptly and accurately, and will continue to do so indefinitely.

They require practically no care or attention. All one has to do is to note the changes indicated by the position of the hand which always registers the exact atmospheric pressure at the time the instrument is observed.

Besides the hand which registers the air pressure there is also one which the observer can adjust so that any subsequent change may be noted. A third hand is sometimes added. This third hand indicates the pressure at sea level (mid-tide). This sea level hand must be set so that it indicates the pressure at sea level. It moves with the pressure hand, and therefore must be set for the elevation where the instrument is to be used.



POCKET ANEROID BAROMETER.

Aneroid Barometers may be placed almost anywhere. They are as portable as a watch and may be carried in the pocket, hung upon the wall or placed upon the desk. They are made as small as a watch charm and as large as a town clock and

of all intermediate diameters, being equally accurate in every size, possessing in some instances sufficient delicacy to indicate the variation of pressure between the height of an ordinary table and the floor upon which it stands.

When made to carry in the pocket they are known as Pocket or Mountain Aneroids. Such instruments are graduated in feet, so that elevations may be noted.

In order to comprehend the work of a Barometer, let us imagine ourselves at the bottom of an ocean of air some 40 miles deep, the surface of which suffers agitation and rolls in waves as do the waves of the sea. This air presses on everything within about ten miles of the earth's surface. We do not feel its weight because our *bodies are filled with air*, but we do feel its currents, the winds.

The weight of the air or force of its pressure at sea level is about 15 pounds to the square inch, but this pressure is constantly changing. The cause of these variations in weight or pressure as indicated by the Barometer is to be sought for, according to Prof. Muller, in the unequal distribution of heat over the earth's surface. This distribution of heat constantly varies. The pressure is likewise disturbed at every moment and currents of air arise which strive to restore the balance. The air is then in constant motion, sometimes more heated and then lighter and then cooler and consequently more dense and heavier. It is these changes in the weight or pressure of the air that causes the hand of the Barometer to oscillate, thus faithfully giving indications of increased or diminished air pressure. In ascending or descending the hand of the Barometer may be seen to move like the hand of a watch. It will thus show, if properly adjusted, the height above the level of the sea or the difference of level between two stations or even the height of its owner's dwelling.

The hand of the Barometer, if the instrument is correctly adjusted and at sea level, will stand practically at 30, this number corresponding to the 30 inches of a Standard Mercurial Barometer. Of course it will vary from this somewhat, owing to the constant changes noted above, but the mean pressure is about 30 inches. On ascending, the hand will move backward or toward the smaller numbers, 29, 28, etc.

Each of these numbers represents practically 1,000 feet, so that upon ascending 1,000 feet the hand of the Barometer will have moved from one number to another. For instance, if the hand stands at 29 and the instrument is carried up 1,000 feet it will have moved to about 28, provided no change except elevation has taken place. The divisions between these whole numbers vary somewhat on different instruments. On some instruments the scale is divided into hundredths of the whole number. Each division then represents 10 feet. On other instruments the divisions are in fiftieths of the whole number, each division representing 20 feet. Well made Ba-

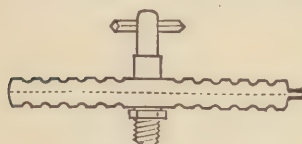


FIG. II.



FIG. III.

rometers are so sensitive that the elevations and depressions of a railroad bed will be shown even on the swiftest moving trains.

Tourists or automobilists can hardly consider their outfit quite complete without an Aneroid. They will be found both useful and instructive companions. They not only indicate weather conditions, but also elevations, as noted, and if graduated for the latter will be found quite accurate.

In order to convey a correct idea of the mechanical and physical structure of the Aneroid, an illustration of its movement is here given. Fig. 1 clearly shows the general construction of the movement with its elastic metallic drum, called the vacuum chamber, "A," upon which the pressure of the atmosphere produces the effect shown in Fig. 3. One head of this drum is firmly secured to the base plate of the instrument, the other is attached to a powerful mainspring, the force of which is applied to overcome the pressure of the atmosphere. This spring lifts the upper part of the chamber, drawing the two drum heads apart. The power of the spring, being just sufficient to overcome the atmospheric pressure upon the vacuum chamber, produces a perfect balance.

Fig. 2 shows the chamber before the air is exhausted and after the force of the spring has been applied. Any variation in air pressure will now be shown by a movement up or down of the elastic chamber. A decrease in pressure allows the spring to overcome the power of the vacuum and the action is upward. Any increase of air pressure produces the contrary result.

This slight movement up or down is greatly multiplied by a series of levers, shown in Fig. 1, one of which is attached to the main spring, the others operating the indicating hand. These levers can be made longer or shorter by adjusting screws, enabling the manufacturer to adjust the instrument to the graduated scale on the dial.

Each instrument is provided with an adjusting screw, by which the indicating hand can be set to the correct position on the dial. This screw extends through the base plate to the back of the instrument and can be operated through an opening in the case.

*Rule for Foretelling Weather, Adapted for Use with the
Aneroid Barometers.*

The words "Stormy," "Fair," "Rain," etc., upon the dial are simply relative, as it does not follow that the weather conditions indicated by these words will necessarily exist when the hand points to them. The meaning, for example, when the hand points to the word "Fair" is that the atmospheric pressure at that time is favorable to fair weather.

In forecasting weather there are several conditions other than atmospheric pressure which must be taken into consideration, viz.: The direction and force of the wind, the humidity of the air, and, most important of all, a comparison of the daily Barometer readings with the indicated pressure of several days preceding. A single observation of the Barometer without reference to the conditions prevailing at definite intervals preceding is liable to be misleading. The important thing to know is, has the rise or fall been slow or rapid or has the Barometer been stationary for some time? Generally speaking, a gradual but steady rise indicates settled weather. A gradual but steady fall indicates unsettled or

wet weather. A rapid rise indicates clear weather with high winds. A sudden fall indicates a sudden shower or high winds or both. A stationary Barometer indicates a continuation of the existing conditions.

To the traveler or tourist a pocket altitude Barometer is second only to the camera in adding interest to a journey or holiday, wherever or however taken.

On account of its size ($1\frac{3}{4}$ inches and $2\frac{1}{2}$ inches diameter) it is very portable, weighs but a few ounces, and with ordinary care will last a lifetime.

Quality counts a good deal more in an instrument of this character than one would imagine. People buying such an instrument are apt to purchase a cheap and useless one, not understanding their value from a manufacturer's standpoint.

Accuracy is a most necessary point, and, of course, on this the value of the instrument depends. True they can be purchased for a few dollars; so can a watch, but *everyone* does not carry a cheap watch.

It is beyond most people to imagine such a small instrument measuring the height of hills and mountains. They cannot see the mechanism and consequently have their doubts.

Compensation to a mountain or traveling aneroid is as essential as is a hand to a clock. A Barometer, accurate as regards its range of scale, if compensated is accurate in any temperature. If, however, it is not compensated, it is accurate only at the temperature in which it was tested. That temperature is absolutely unknown to either the buyer or the purchaser.

Compensation is accomplished by brazing a piece of steel to the main arm of the Barometer, which is of brass, and since the expansion of steel is less than brass, when a change of temperature occurs, the steel tends to hold the expansion of the brass in check, causing it to curve slightly, maintaining the distance between its two ends, consequently the leverage is not affected.

In non-compensated instruments, this expansion is a source of material error, and care should be taken in purchasing a compensated instrument, to see that it really is compensated. It cannot be affected at present by any other means than by

the adjustment of the two metals, and some movements, on account of their peculiar construction, will not admit it.

The altitudes covered by watch and pocket aneroids vary from 3,000 feet to 20,000 feet, naturally those of low altitude range show a finer division of measurement than those divided to 15,000 or 20,000 feet.

These aneroids have their scales of feet divided in unequal quantities, diminishing as the altitude increases. The reason for this is that the higher we ascend, the more rare or thin the air becomes. A smaller quantity will fill a certain space above sea level than at sea level.

The earth's attraction draws each particle of air downward. The surface of the earth at sea level bears the weight of miles and miles of air overhead. The bottom layers as a consequence bear the weight of all those above.

The true relation of the altitude and pressure scale of the aneroids exists only with the "0" feet of the former at the 31 of the latter.

If before the ascension of a hill the hand points to 900 feet on the altitude scale, make a note of it. At the summit it reads 2,045 feet we will imagine. The altitude is 2,045 feet less 900 feet, or an altitude of 1,145 feet.

By intelligent study weather conditions can be prognosticated with a fair degree of accuracy, excursions can be planned and many trips taken which ordinarily would have been uninteresting, would be filled with interest and delight, to say nothing of the education derived.

On foot or horseback, in railway travel or at sea, be you a pedestrian or a balloonist, your trips will double in interest if you have as a companion an altitude Barometer.

FIELD GLASSES.

The number of people who desire a good Field Glass is multitudinous, but the number who know how to select one that will prove satisfactory is very small indeed. There are a number of points that should be kept in mind when selecting a glass. First, the atmospheric conditions under which the glass is most likely to be used; second, the steadiness of the arm that is to hold it; third, what particular objects are to be viewed; fourth, the distance at which the observer wishes to view objects; fifth, are they celestial or terrestrial?

The desirable points in a Field Glass are: First, clear definition; second, great illumination; third, great magnifying power; and fourth, large field. It is impossible to have all these desirable qualities in a single glass. One of them, at least, must be sacrificed. For instance, great field and great power cannot be had in the same glass, for the higher the power the smaller the field is bound to be. It is also true that the illumination is decreased as the power of the glass is increased, and, of course, this decrease of light affects the definition. Therefore, great power is desirable only when atmospheric and other conditions are perfect and when a small field would be perfectly satisfactory, as when looking at the moon or stars.

If the observer were at the top of Pike's Peak on a bright, clear day the conditions would be fine for a high-power glass, for at that elevation the atmosphere is very dry and free from other matter that would obstruct clear vision. A twelve-power glass (or one that magnifies 144 times) under such conditions would give excellent results, provided the pupillary distance were correctly adjusted and the glass were sharply focused and held quite rigid, but under ordinary conditions a glass of half or two-thirds of the above power would prove far more satisfactory. A glass magnifying 18 diameters, or 324 times, would be a joy to possess under the above conditions, but would be practically worthless under ordinary conditions.

We must remember that when we look at an object ten miles distant, that we are looking through ten times as much vapor as we are when viewing an object one mile away. We must also remember that all obstructions to clear vision are

magnified by the glass to the same extent as the object is. It is the moisture and other obstructions in the air that cause distant objects to be more or less dim or hazy.

The writer once heard a marksman say: "If the air were as clear where the target is as it is here I would be able to make a better score." Possibly the air surrounding the target was clearer than that surrounding the marksman.

Glasses of high power must be held very rigid, especially when looking at small objects at any considerable distance. For instance, when looking at the name on a steamer a mile or so away, the glass must be very rigid, for the slightest movement of the glass will cause the line of vision to be directed a hundred feet or more away from the name.

For this and other reasons glasses having comparatively low power are more suitable for viewing small objects at a distance than are those of high power. If the atmospheric conditions were perfect we would be able to see an object as distinctly four miles with a four-power glass as we can one mile with the naked eye; but it is a fact that they are never perfect, for there is always more or less moisture in the air, and there is usually four times as much in four as there is in one mile.

The modern Field Glasses, known as "Prism Binoculars," afford a much larger field than the ordinary styles do. They are also more compact, lighter and more comely than the old style. They are, most of them, made adjustable for pupillary distance which is a great advantage, especially to a user whose pupils are wide apart, or narrower than the average eyes. Many of them are small enough to be carried in an overcoat pocket.

Field Glasses having large objectives conserve more light than those with small ones. This conservation of light is exceedingly important, for the reason that the light emanating from an object viewed through a glass is spread over a large area of the retina. This area is in proportion to the magnifying power of the glass.

Suppose, for instance, that we view an object one foot square through a glass that magnifies this square four diameters. Our magnified square would be four feet high and four feet wide. It would then take sixteen of our original squares

to cover this magnified one. Therefore, our objectives should have much more than sixteen times the area of the pupil through which the light must pass to reach the retina, or the object would not be sufficiently illuminated to be seen distinctly. We say "more than sixteen times," for the reason that much light is lost by reflection. The objectives of a Field Glass gather and condense the light, and the larger the lens the more light it gathers, and it is the light that we get from an object that enables us to see it.

The ordinary Field or Opera Glasses with large objectives are superior to those of the same power having small objectives, for the reason that they gather more light.

THE TELESCOPE AND HOW TO USE IT.

The refracting telescope consists of a single convex lens, usually spoken of as the "objective," and an eye piece, or ocular, which may consist of one or more lenses. The office of the objective is to form an image of a distant object, and that of the eye piece is to enable the operator to view that image. The telescope in its simplest form consists of two convex lenses—one (the objective), being a lens having a great focal length, and the other (the ocular), being a lens having a short focal length.

The objective, because of its great focal length, has very little magnifying power, but the ocular, having a short focal length, has great magnifying power. It therefore acts like a microscope, enabling the operator to view the image formed by the objective greatly magnified.

When a telescope is arranged for distinct vision of a distant object the distance between the two lenses is equal to the sum of their focal lengths. The image of the object being examined is formed in the common focus of the two lenses, and the pencils of light proceeding from the image consists, after refraction at the eye lens, of parallel rays which are the most favorable for distinct vision.

The magnifying power of such an instrument is represented by the ratio of the focal length of the objective to

that of the eye lens. For instance, if the objective has a focal length of 20 inches and the ocular a focal length of 2 inches, the magnifying power is 10 diameters, which equals 100 times.

It will be seen by the above that the magnifying power of a telescope may be increased either by increasing the focal length of the objective or by diminishing the focal length of the ocular or eye lens. The latter means, however, cannot be resorted to without increasing both the chromatic dispersion and the spherical aberration, both of which interfere materially with sharply defined images, and therefore with distinct vision.

Hence, before the introduction of chromatic lenses, the most satisfactory way to increase the power of an instrument was to increase the focal length of the objective, and this is what our first astronomers did. A celebrated one of them used an objective having a focal length of 120 feet; this he fastened to the end of a pole. He called his instrument an "aerial" telescope.

Instruments such as described above, or those having but two lenses, are known as "astronomical" telescopes. The image produced by the objective is inverted, but this inversion of celestial (heavenly) bodies does not materially inconvenience the observer.

Refracting telescopes, used for astronomical purposes, are now made with achromatic objectives, and either Huyghenian or Ramsden eye pieces. The former being preferable for the reason that they conserve more light than do the latter:

When terrestrial objects (objects on terra firma) are to be viewed, they should appear erect; therefore the inverted image of terrestrial objects must again be inverted by the eye piece. Such an eye piece is known as a "terrestrial" eye piece. The terrestrial, or erect eye piece, used for this purpose is in fact a compound microscope, consisting of an objective lens, an amplifying lens, a field lens and an eye lens. The two latter forming either a negative or a positive eye piece.

The inverted image formed by the objective is again inverted by the eye piece; therefore the image as viewed through the eye lens is erect and greatly magnified. In consequence of the great loss of light consequent upon this style of construction, navigators years ago used the simple two lens telescope, described above, when sailing at night. They were often called "night glasses." The inversion of the images caused but little inconvenience when used in the twilight or in moonlight.

Owing to vastly improved lenses and to more perfect mechanical construction, such glasses have been almost entirely superceded by the modern binocular instruments known as "field glasses," or when made quite small, as "opera glasses." By using a concave lens for an oculare in place of a convex one, a simple telescope is formed having only two lenses. Such a glass shows objects erect. This style of glass is known as a "Galilean" telescope. Usually two of them are mounted together—one for each eye; thus making the instrument binocular rather than monocular. As binocular vision is far superior to monocular, so is the binocular telescope, commonly called a "field glass," superior to the monocular one, especially for the ordinary uses to which such a glass is put. The magnifying power, as in the astronomical style, is represented by the ratio of the focal length of the objective to that of the oculare.

Recently great improvements have been made in this style of glass, not only by using achromatic lenses, but by introducing prisms into the tubes of the instrument. These prisms allow the use of an objective having an increased focal length. The prisms cause the pencils of light that pass through the objective to be doubled upon themselves; thus they pass back and forth in a short tube and finally reach the eye piece. This doubling of the light back and forth causes the image of the distant object to be erect at the eye piece, and this in turn allows the use of an ordinary compound eye piece of any practical power to be used.

The focusing of the binocular instruments is made easy and practical by the use of a rack and pinion, which moves the eye piece of both tubes back and forth simultaneously.

Some of the high power instruments have a separate focusing eye piece for use in cases where the refraction is not the same in both eyes.

Binocular glasses containing prisms are known as "prism" binoculars, or when made with their objectives further apart than are the eye pieces, thus producing a stereoscopic effect, they are known as "stereo" binoculars.

The magnifying power of the prism binoculars is usually stamped upon the glass. They are made having a power of 4, 6, 8, 10, 12, 15 and 18 diameters: meaning that an 8 power glass magnifies 8 diameters. Such an instrument shows the image 64 times as large as was the original one formed by the objective.

High power instruments or those that magnify more than 10 diameters are of little value except on very bright days, and then only when in the hands of a steady person, or when used in connection with a tripod. High power instruments must be held practically rigid.

The most important part of a telescope or field glass is the objective, which should be as large and as perfect as the price of the glass will permit. A few objectives have been made having a diameter of 30 to 40 inches. Such a lens gathers a great amount of light, which is condensed to an area as small as the pupil of an eye. It is then exceedingly bright.

The objectives of an ordinary telescope range from one to three inches in diameter, and those used in opera or field glasses range from one to two and three-eighths inches.

The above glasses are principally produced in France, and the size of the objectives is given in lignes. A ligne is practically $\frac{1}{11}$ of an inch; therefore an 11 ligne opera glass has an objective 1 inch in diameter. The objective in a 24 ligne telescope or field glass measures practically $2\frac{1}{8}$ inches.

The usual size of glasses called "opera" glasses is 11, 13, 15 and 17 lignes, and those known as "field" glasses are 19, 21, 24 and 26 lignes. The power of opera and field glasses ranges between 2 and 7 diameters; the latter instrument must have large and thoroughly achromatic objectives and should have achromatic oculars also.

The field of view decreases in proportion to the increase of power; therefore the field of a high power telescope is very small. It is also true that the magnifying of the image decreases the apparent illumination. For this reason eye pieces with varying powers should be used in astronomical telescopes. If the object be highly illuminated a higher power eye piece may be used than could be if there was but little light, as on a dull or cloudy day. The prism binoculars afford a much greater field than that afforded by the ordinary glasses.

When the atmosphere is clear, terrestrial objects may be viewed with a telescope having a magnifying power of 10 to 20 diameters. Higher power than this cannot be used advantageously unless the objective be of extra large size or the weather be unusually clear and bright.

Binocular instruments enable a person to use both eyes when viewing objects. Such instruments transmit to the eyes double the amount of light that monocular ones of the same size do; therefore objects look brighter and more distinct than they do when viewed with a single eye.

Field glasses, like telescopes, are sometimes provided with two eye lenses, a weak and a strong one; the latter being used for day and the former for night use. When using the ordinary 10 to 16 ligne telescope they may be held in the hands, but better results are obtained if they are mounted on a tripod or held against something that is rigid. Those larger than the above must be mounted on tripods or stands that will allow free movement in all directions and yet hold the instrument rigid as desired.

Instruments having great power are mounted on stands having mechanical appliances for directing them, and those used in observatories are moved by clock work, which may be so timed that the telescope moves with the star being observed.

The focusing of a high power instrument is accomplished by rack and pinion, but those held in the hand must be focused by pushing the eye piece tube in. The best results are obtained if the instrument is extended to its full length; then the eye piece should be pushed in by a twisting motion,

until a sharp image is obtained. The telescope should be directed towards an object, like a house, some distance from the observer; it should be held rigid and the eye piece adjusted until the sharpest image possible is obtained.

If the object is one-fourth of a mile, or more, away, the instrument if sharply focused on it will be in focus for all objects at a greater distance. If the owner, after once focusing the instrument, will mark the eye piece tube at a point close to the end of the next draw, he will be able to place the telescope nearly in focus before attempting to view an object.

Binocular instruments, whether opera, field, or prism glasses, must be in perfect alignment or objects viewed through them will be seen double. They may be thrown out of alignment by a fall or by a severe jar. When in such condition they should be placed in the hands of a competent person for readjustment. The lenses should be kept perfectly clean; they should never be wiped with anything but a perfectly clean and soft material like silk or chamois leather.

The interpupillary distance, or the distance between the eye pieces of high power instruments, must be the same as the distance between the pupils of the one using the instrument. If the eye pieces are wider apart or closer together than are the eyes of the user, either only one eye will be used or the light will be so diminished that good results will be impossible; therefore all high power binocular instruments should be made so that the distance between the eye pieces may be varied to suit the user. In such instruments the bars holding the two tubes together are jointed in the middle, allowing the tubes to be wide apart or close together. When the pupillary adjustment is correct practically all the light caught by the objectives enters the observer's eyes.

As stated above, the field of high power astronomical telescopes is very small. This makes it a difficult operation to direct the telescope so as to bring the particular star that it is desired to observe into the field of view. Therefore a small telescope, called a "finder," is attached to the large one; the small one being so adjusted that when the

star is in view through it, it will also be in the field of the large one.

All telescopes used for observing the sun should have a dark glass over the eye piece. Such a glass is needed to protect the observer's eye from the heat and the great flood of light produced by the objective. The dark glass must be removed when the telescope is used at night. It should always be in position except when the instrument is being used as above. This dark glass not only protects the observer's eye when viewing the sun, but it also protects the delicate eye lens of the instrument. Field glasses should, and usually do, have sun shades. They are mounted on the tubes of the glass and may be extended over the objectives. They prevent the sun from shining directly upon the objectives. The shades are particularly useful when the object being viewed lies in the direction of the sun.

THE RADIOMETER.

That rays of light exert a mechanical pressure upon a body upon which they impinge is proven by Crooke's Radiometer. This instrument also proves that this pressure or energy is practically annulled if the light is absorbed as when impinging upon a blackened surface. Direct solar rays or sunlight exerts about 0.4 milligrams of pressure upon each square meter of blackened surface and about 0.8 milligrams or double the amount if the surface is polished so that the light is perfectly reflected, the light in both instances being incident normally. If the ray be reflected perfectly its energy must be added to that of the incident ray.



RADIOMETER

The instrument known as Crooke's Radiometer consists of four or more platinum vanes mounted on an exceedingly light frame work which is pivoted on a fine needle point so that friction when revolving is reduced to the minimum. The whole is enclosed in a glass tube which is highly ex-

hausted ; the vanes then practically revolve in a vacuum and are, therefore, not affected by currents of air. Each vane is blackened on one side and polished on the other. When the instrument is exposed to light, the rays that strike the blackened surface of the vanes are absorbed, and they therefore lose a part of their force, but those that are reflected upon the polished surfaces augment their power because of this reflection.

When light is absorbed by a blackened surface, the temperature of the absorbing surface is raised somewhat, and this heat causes the light to rebound with greater velocity than it had when striking the blackened surface. The vanes are then made to revolve as if the blackened surfaces were repelled by the light to a greater extent than are the polished surfaces.

Light then exerts a true pressure upon a surface upon which it impinges, this pressure being twice as great for a reflecting surface as for an absorbing surface.

The absolute magnitude of this pressure is exceedingly slight but the vanes of a Crooke's Radiometer and their mounting are very light and are made so that they will spin like a top on a minute steel point resting on a polished glass surface, the whole being practically in a vacuum so that currents of air from any direction cannot exert particle of pressure on the vanes. Under these conditions the slightest pressure causes the vanes to revolve.

The rise of temperature at the blackened surface does not penetrate to the opposite or polished surface of the vanes, thus the action and reaction of the light is equal and opposite. When the vanes are revolving the pressure is exerted on the blackened and polished surfaces alternately causing them to revolve. Direct sunlight exerts a greater pressure than does artificial light, unless the latter is very strong, but either will cause the vanes to revolve with greater rapidity if it be strong. Light that is reflected from surrounding objects travels in many directions, therefore its force is not all applied in one

direction. Such light has not the power to revolve the vanes rapidly, but if the light from a single source predominates, the vanes will be set in motion by it, showing that all light has more or less force according to its volume and direction.

INSTRUCTIONS FOR THE USE AND CARE OF ARTIFICIAL EYES.

Artificial eyes are made of glass, and are extremely fragile and delicate, and the best of care has to be taken of them to guard against breakage.

No artificial eye can be guaranteed against breakage for any length of time, as they are apt to break without any seeming reason, owing to contraction or expansion on going from one temperature to another, if the change is great and too sudden, or to break if taken out of the socket and put into cold water, or vice versa.

Extreme care should always be taken to keep artificial eyes always clean and sanitary, and when the eye is not in the socket, it should be kept in water, or carefully cleaned and put away, if it is not to be used for sometime.

If an artificial eye is not kept clean it is apt to color, and there are times when it will color, no matter how carefully it has been kept, owing to the character of the secretions in the socket, and this coloring cannot in any way be prevented. This should be understood by the wearer to be due absolutely to peculiar circumstances in his own case, for which no one can be held responsible. If when the eye is removed or inserted it be placed in luke warm water and allowed to cool gradually the danger of breakage is reduced to the minimum.

EDUCATION AND SUCCESS.

No amount of elasticity of conscience will compensate for lack of diligence in the study of one's business, whether it be commercial or professional. A practical education is the winning trick in almost every trade or business, and a technical education is the sole safe way to success in any of the secular professions.

It is said that the wicked often flourish, but the ignorant never. The world at large has respect for the man or woman who knows something, and that respect becomes profound if they know something, and know that they know it. It is true that we can make little use of any knowledge that has been gained in "parrot-like fashion," whether it be commercial or technical, for intelligence and perseverance must go hand in hand with knowledge if we are to reap a goodly share of this world's rewards. Knowledge, intellectual capacity and common sense are all needed by the man or woman who is to be recognized as a successful merchant, craftsman or practitioner.

Only less important than the scientific knowledge upon which rests the claim to a professional standing is the study of ethics, business methods and the art of buying. We do not mean by the art of buying that we are apt to purchase cheap material in the cheapest market, regardless of the real merits of that which is bought, but we do mean that it is a real accomplishment, a real art, to purchase the best that the market affords at a price that is fair to all those who produce and distribute these articles.

There is something almost dishonest in the conduct of one who professes to carry on a high-class practice and yet whose purchases are made regardless of anything and everything except price. Meritorious material, uniformly accurate work, prompt service and absolute fidelity all must be considered when seeking a market in which to purchase advantageously.

The best market or the best base of supplies is the one where all of the above are to be relied upon. The art of buying consists in knowing what to buy and where to buy it. If we know all about the best that the market has we will

know what to purchase; therefore a thorough knowledge of what is to be had is important. It is also important that the purchaser should be able to recognize good material and superior workmanship, for these make the article valuable. Labor, if it be skillful, often represents the greater part of the cost of an article; therefore the workmanship displayed must always be carefully studied if we are to know that we are purchasing at the best price. Many times the cheapest articles prove in the end to be the dearest that could have been bought.

It is only reasonable to suppose that a cut has been made in both the quality of the material and in the workmanship on every article sold at a cut price. If we know the real value of an article we can purchase it at cut rate prices, but articles of real value are rarely sold at such prices. The skillful mechanic, like the skillful surgeon, is entitled to receive for his labor a price above the average. It therefore behooves every one to be skillful if they wish to be successful, and to be skillful one must work and study. Reading and practical work are complementary to one another. Both are necessary to the man or woman seeking to attain a high position in his or her calling. The leading men in all walks of life today are the learned ones. The twentieth century man must know more than the nineteenth century one did, but the facilities for obtaining knowledge and experience are far superior today than they were a few years ago. Trade journals filled with technical and practical ideas abound, post-graduate schools, where special instructions and practical experience with abundant clinical material are within the reach of all.

Ethics to the professional man are like business methods of the merchant—they must be studied carefully and guarded jealously, for upon them rests the foundation of a professional man's career. The professional man, like the merchant, must study business methods as well as the ethics of his profession. He must be a good accountant, a good collector and a good payer as well.

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